# The Blast Furnace and Steel Plant

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The Blast Furnace and Steel Plant

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# Inspection of Clairton Coke Plant

### On a General Inspection Trip, the Engineers Society of Western Pennsylvania Visit the By-Product Coke Oven Plant of the Carnegie Steel Company at Clairton, Pa.

By F. F. TRESCHOW.

ONE hundred and fifty members of the Engineers Society of Western Pennsylvania visited the by-product coke oven plant of the Carnegie Steel Company at Clairton on Saturday afternoon, November 6, the party was divided into groups of 10, each group being furnished with a guide. They were first shown the methods of unloading, screening and conveying the coal.

The coal used is known at Klondike (Fayette county) and is transported by barges holding 800 to 1,000 net tons from the mines on the Monongahela river which are located 30 to 55 miles from Clairton. The coal is a high volatile of the following average analysis:

| | |
|---|---|
| Moisture | 2.58 |
| Vol. Mat. | 34.04 |
| Fix. Car. | 57.26 |
| Ash | 8.70 |
| Btu | 13,157 |

The coal is unloaded at two points by electrically operated coal hoists. Each hoist consisting of two five-ton capacity buckets. Each hoist has a capacity of 500 net tons per hour. The coal is screened through shaker screens and sizes over 2½" are crushed. It is then conveyed by belt to the coal storage bunkers over the ovens. There are four bunkers in all and each one holds 4,000 net tons and supplies three batteries. The coal is distributed to the ovens by larry cars running over the tops of the batteries. The ovens are Koppers type and hold approximately 13.4 net tons to a charge. The charge is held for approximately 18 to 19 hours and is then pushed out by electrically operated pushers into quenching cars and the hot coke quenched with water. From the quenching cars it is discharged upon the coke wharf and from there, belt conveyed, to the screening station where it is divided into metallurgical coke for blast furnaces, domestic coke and coke dust. A days run at Clairton involves the following quantities:

| | |
|---|---|
| Coal Charges | 12,500 Net tons |
| Blast Furnace Coke | 8,165 Net tons |
| Domestic Coke | 412 Net tons |
| Coke Dust | 779 Net tons |
| Tar | 136,200 Gals. |
| Ammonium Sulphate | 321,350 Lbs. |
| Light Oils { Benzol<br>Toluol<br>Solvents | 38,900 Gals. |
| Naphthalene | 1,280 Lbs. |
| Surplus Gas (570 Btu cu. ft.) | 78,700,000 cu. ft. |

The volatile products from the coal are led through mains along which 90 per cent of the tar and water vapors are condensed and collected. These mains discharge the gas into the primary coolers which remove about 8 per cent more tar and water vapors. In these coolers the gas is cooled by indirect contact with water. These coolers are similar to a surface condenser. The gas is pumped by five Connersville exhausters, each capable of handling 40,000,000 cu. ft. in 24 hours at 100 rpms. These exhausters are Corliss engine driven. After the exhausters the gas is passed through the saturators which contain a dilute solution of sulphuric acid (5 per cent) and the ammonia in the gas forms ammonium sulphate. This is dryed by centrifugal whirlers and sold as fertilizer. The gas then continues to the scrubbers where it comes in direct contact with a petroleum product called wash or straw oil, which absorbs the light oils to about 3½ per cent of its volume. This mixture is then pumped to the benzol plant where the light oils are stilled off and the wash oil returned to take up more light oils.

At the benzol plant the light oils are further separated by fractional distillation into motor benzol, toluol and solvents. The gas after having the light oils removed is called debenzolized gas and is used as fuel at the Clairton, Duquesne and Homestead plants of the Carnegie Steel Company. This gas is pumped by turbine driven blowers through a 40-inch diameter line, nine miles long.

All the steam generated at the plant is from Stirling boilers with Coxe Stokers burning coke dust. The electric power is generated 6,600 volts, 25-cycle, 3-phase and transformed or converted at different points when needed to 250 volts ac or dc.

A comprehensive description of the Clairton by-product coke plant appeared on page 256 of the June, 1919, issue of THE BLAST FURNACE AND STEEL PLANT. It was written by Frank F. Marquard and was presented by the author before the New York meeting of the American Iron and Steel Institute of that year. Included is a table of the operating organization and a detailed list of the equipment included.

# Reversion of Phosphorus to Basic Steel in the Ladle

## The Conditions Upon Which the Quantity of Phosphorus to Revert Depends—Fundamental Cause of the Reversion of Phosphorus Due to the Presence of Reducing Elements.

By **HENRY D. HIBBARD.**

TOO high phosphorus in finished basic steel may be the result of incomplete dephosphorization in the furnace or the return (reversion) of phosphorus from the slag to the metal in the ladle. The reversion of phosphorus was encountered soon after the basic processes were introduced, 40 years ago, and still takes place causing sometimes serious trouble such as the rejection of steel which otherwise is within specifications, and was wholly so before tapping.

The fundamental cause of the reversion of phospohrus is the presence in the steel of reducing elements added to give the composition desired, aided, usually, by the entrance into the slag of silica ($SiO_2$) taken up from the ladle lining.

Assuming that dephosphorization has been sufficiently well done in the furnace and no slag has been run off, the phosphorus of the charge is nearly all in the slag when it is poured from the furnace into the ladle. The ladle for economical reasons has always an acid lining, high in silica, consisting of clay bricks or a mixture of clay and ganister (quartz) with perhaps some graphite admixture. This lining is attacked by the bases of the molten slag, particularly by the lime, is fluked and enters the slag increasing the percentage of silica therein. This silica sets free more or less completely the phosphoric acid from the lime with which it is combined, and then the reducing elements.

Silicon manganese and carbon reduce the phosphoric acid to phosphorus which is at once absorbed by the molten metal in the form of phosphide of iron. Silicon acid ($SiO_2$) seems to be the strongest acid present at hearth temperatures and therefore displaces the phosphoric acid and unites with its base. This transfer of phosphorus from the slag to the metal takes place on the contact surface of the metal and slag which after the charge has come to rest in the lade, is a plane. Tht increased area of contact from the mixing caused by the slag running into the ladle, and because of any boiling due to the escape of gas formed by the oxidation of carbon in the ladle, will for the moment increase the area of contact but the time is so short that the slag will not have attacked the ladle linnig appreciably nor will any noteworthy amount of phosphorus be reduced during that period. The quantity of phosphorus to revert depends on the six conditions which are now considered.

1. The quantity of phosphorus in the charge and hence the quantity and percentage of phosphorus (as phosphoric acid $P_2O_5$) in the slag. The ihgher the percentage the more of it gets back into the steel under a given set of conditions. When all the slag is retained in the furnace until tapping its content of $P_2O_5$ will usually be 10 or 15 times that of the average phosphorus in the charge materials. When a charge of ordinary ingot steel averages under 0.20 per cent of phosphorus, the slag should have not over 2 or 2½ per cent of $P_2O_5$ and no serious trouble is to be expected from reversion of the phosphorus. With low carbon and molds so large that not over 20 are required to take the whole heat no harmful reversion should take place with twice that content of phosphorus. On the other hand, a steel casting charge to be poured until a hundred molds or more should not have more than 0.25 or 0.30 per cent of phosphorus in the charge and preferably not over half that percentage, or there will be danger of serious reversion.

2. The increase of silica in the slag from the ladle lining scorification has as previously stated an important effect on phosphorus reversion. The obvious cure or means of prevention of this increase seems to be the use of a basic ladle lining, instead of acid but the cost of such a lining has so far been too great though it has been proposed and even patented. Basic refractories cost many times as much as acid per unit and so far their durability has not been great enough to affect this. The erosion of the acid lining by the basic slag is expensive because of the short life of the lining and a cheap basic lining is much to be desired. With ample supplies of basic slag costing nothing which a moderate amount of other basic or neutral material might make sufficiently refractory the case does not seem hopeless. The scorification or fluxing of a basic lining by a basic slag would be far more durable than those now used provided it were not damaged as by removing skulls left by charges cast too cold. Chromiferous slags have particularly high melting points.

(a) In a 25 ton basic open hearth melt for projectile blanks of which 130 were cast taking about 30 minutes, the silica in the slag sometimes rose from 17 per cent to 26 per cent and the phosphorus in the metal from 0.045 per cent at the start of teeming to 0.065 per cent at the end causing rejection of a part of the steel, that is, the latter part of each heat so affected. In other heats,

0.017 per cent P rose to 0.029 per cent
0.021 per cent P rose to 0.045 per cent
0.059 per cen P rose to 0.067 per cent

The practice was followed of numbering the ingots so as to tell those cast of metal too high in phsophorus from those cast earlier in which the phosphorus was sufficiently low.

3. The percentages in the finished steel of reducing elements, chiefly silicon manganese and carbon. To re-enter the metal the phosphorus must be reduced from its acid, $P_2O_5$, to form phosphide of iron and that requires the consumption by oxidation of

a reducing element, or elements, usually one or more of those mentioned above. Thus steel for castings being high in silicon will reduce phosphorus more extensively than ordinary grades of ingot steel intended to be rolled to finished sizes and shapes. Low carbon steels will suffer less from this cause than those with higher carbons. Steel with 3 per cent of chromium has been found to have exceptionally great reversion.

4. The quantity of slag retained in the ladle floating on the metal. This quantity is most important for the less there is of it the less reversion of phosphorus will take place. The best practice demands that the ladle shall be just large enough to hold the metal of the melt and from 4 to 6 inches of slag to act as a covering blanket to prevent too rapid escape of heat from the metal and to keep air away from it during teeming. The remainder of the slag should be run off into the slag pot or thimble through an ample notch in the edge of the ladle and launder to match. Most ladles in use are too large, retaining therefore too much slag and have too small slag notches so that much of the slag overflows the ladle rim and falls on the pit floor from which it is shovelled later, a hot and unnecessary task. The 4 to 6 inch layer of slag mentioned will usually solidify for the most part and remain comparatively quiet and motionless.

5. The consistency of the slag retained in the ladle. This governs reversion closely. If the slag is thick so that it lies motionless, reversion is practically limited to the phosphorus in the layer of slag actually in contact with the steel. If however the slag is fluid, convection currents will be set up in it because of change in specific gravity due to cooling, or set in motion by escaping gas bubbles, and fresh portions of slag are presented to the metal for the latter to take phosphorus from. The corrosion of the ladle lining is also more rapid when the slag is thin and fluid which proportionately increases the silica of the slag and thereby facilitates the transfer of phosphorus to the metal for reasons already considered. To thicken the slag in the ladle in order to check both scorification of the lining and reversion of phosphorus a few shovels of basic material, usually lime, limestone or dilomite is thrown in immediately after the charge has all run out of the furnace into the ladle. This addition cools and thickens the slag and so tends t ohold it motionless and thereby to prevent corrosion of the ladle lining, and also acts as additional base to counteract the silica taken up. This latter effect is not usually of moment though it may be when the quantity of slag is large and it is thin and fluid, and particularly when the time for pouring is exceptionally long.

(6) The length of time the metal is held after tapping until it is all turned into the moulds. The time consumed in teeming bears directly on the reversion of phosphorus because the longer it is the more silica will be taken up by the slag from the lining and the more phosphorus is precipitated, to be taken up by the metal which is in contact with the slag for that period of time. The time may vary from a few minutes when a small charge is poured into a few ingots to an hour or more when a 20 ton steel casting heat is poured into 200 molds.

The rise in phosphorus content due to reversion as shown by the analysis of the first and last steel to be turned is fictitiously great as the average is considerably less. The first metal to be teemed has no enrichment and even the first half may have none. The final enrichment is made on a constantly diminishing amount, the maximum being in the last metal to be teemed. If the metal were stirred during teeming there would be less difference between the first and last metal out, though the total phosphorus in the charge might be more because the stirring would aid the absorption of phosphorus.

Thus if the castings or ingots are small those cast last may have too much phosphorus while if large ingots or castings are made the last metal with the highest phosphorus may be diffused in the larger mass of less enriched metal and the whole be within allowable limits.

In this country the phosphorus in basic crude iron is usually about 0.3 per cent and that in the steel scrap under 0.06 per cent. If then the open hearth charge is half crude and half scrap the average phosphorus of the charge is 0.18 per cent and the phosphoric acid in the slag should be about 2 per cent, not a high figure. Hence reversion of phosphorus is not serious in the great bulk of steels made in America.

Excessively strong reducing conditions as for instance the presence in the metal of 0.5 per cent silicon or high carbon or manganese with high temperature for a protracted period of time will reduce phosphorus freely from the slag even though there is no increase in its silica content. In making steel in the electric furnace if complete desulphurization is aimed at nearly all of the phosphorus in the remainder of the dephosphorizing slag, left in the furnace after skimming, will be reduced and re-enter the metal even though the silica in the slag be not over 20 per cent, which is fairly basic.

## ANNUAL MEETING OF THE TAYLOR SOCIETY.

Results of a survey on the advisability of the three-shift system in the steel industry will be made at the annual meeting of the Taylor society, to be held December 2-4, in the Engineering societies building, New York. Other problems which will be discussed are scientific management and standardization of products. Business sessions will occupy the first day. The official program follows:

December 3—Morning: "Scientific Management in the Sales Department", Henry S. Dennison, chairman.

Reports of committees on organization and function of the sales operating department, organization and function of the sales engineering department and the questionnaire.

Afternoon: Discussion of reports.

Evening: Joint session with the management section of the American Society of Mechanical Engineering and the New York section of the American Institute of Electrical Engineers. Presentation of papers, "The Long Day in the Steel Industry", "A Problem in the Engineering of Men", Fred J. Miller, chairman. "The Three Shift System in the Steel Industry", "First Report of a Recent Survey", by Horace B. Drury, United States shipping board. "The Point of View of the Manufacturer", by William B. Dickson, Midvale Steel & Ordnance Co., Philadelphia.

December 4—Morning: "Standardization of Products", John R. Dunlap, chairman. "Standardization of Products as a National Economy", Melvin T. Copeland, Harvard university, Cambridge, Mass.

# Lubrication, Its Importance to Industry

### A Discussion of the Different Methods of Lubrication and Concluding With a Short Description of the Force Feed Pump and Its Adaptation to Present Lubricating Efficiency in Industry.

By **A. H. NOYES.**

EVER since machinery has been in existence, lubrication has been its companion, in fact it existed even before there were machines, when it was simply a case of reducing the power necessary to push one surface over another.

People did not know the word friction, did not even know what lubricant meant, but they did know that a little bit of fat or grease made the sliding a lot easier.

Even today, in the Island of Madeira, the natives' oxcarts have runners instead of wheels, and to assist the patient animal, the driver runs ahead with the "grease rag", with which he smears the cobble stones of the roads. From years of greasing they look like polished ebony.

It is a far call from a wooden sled sliding on cobble stones to two highly polished metal surfaces gliding over each other in a delicate machine, or the powerful piston of a great ship sliding back and forth in the cylinder pushing the whole weight of the ship before it, or the wonderful roller and ball bearings which do so much to reduce friction, and consequently the cost of motive power today.

So it is a far call from the grease rag of the Madeira native to the marvelous automatic force feed lubrication of the present day's genius. If the yelling, gesturing native becomes a bit too tired of running back and forth with his "grease rag" it is only a little more sweat and effort from the patient ox that is at stake, no one is hurt, no damage done, only a little more time wasted, and time is a drug on the market with the natives.

But when two polished metal surfaces slide over each other, unoiled, they have a fatal tendency to stick together. Then what ruin! Bearings destroyed, cars delayed, ships at the mercy of wind and wave, time which is now worth millions, lost, contracts forfeited, and incalculable damage done.

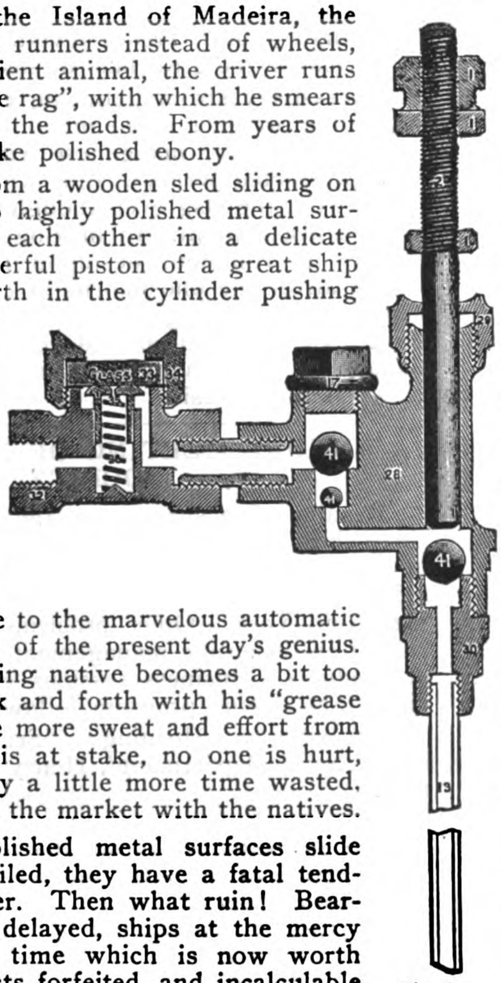


**Fig. 1—Ratchet feed lubricator**

Lubrication then becomes the ***sine qua non*** of industry. This seemingly unimportant thing becomes of prime importance, and must be considered from two viewpoints. The first of these is the selection of the lubricant, and the second is the continuous application of the lubricant to the bearings, in the amount required.

Only a child would attempt to lubricate the highly polished bearings of an astronomical instrument with graphite, or to put crude oil in the delicate movements of a watch, neither would highly refined machine oil be of great service in the bearing of a cement crusher. But between these wide limits there is an infinite number of degrees of refinement, and much of the life of a machine depends upon the selection of exactly the right lubricant.

However, the utmost care and the most expert knowledge might be exercised in selecting just the lubricant suited for a machine, and little use would it be if it never reached the bearings, a poor lubricant that reaches the spot is much better than a perfect one that stays in the oil tank.

This is where the element of human frailty formerly entered. The man with the oil can was often more important than the president of the company, his mistakes would sometimes be more costly, and both the president and the oiler were liable to error.

Men have such excellent "forgetteries". Add to that characteristic the universal tendency to carelessness and to "slighting the job", and you have in humanity a woefully deficient oiling machine.

Some accurate and reliable lubricating instrument had, therefore, to be devised. There were however, certain advantages that the human oiler did have: The machine which should replace him must incorporate all of these advantages to a higher degree, and in addition, it must not get out of order. So came into existence the force feed lubricator.

For instance, the lubricator must start work as soon as the machine starts and must deliever oil in proportion to its needs. A ratchet driven pump was found to best fulfill these two conditions.

But the "man with the oil can" was not affected by heat or cold, and, if working in flying dust, he might rub his inflamed eyes, but he still kept on oiling.

The best modern force feed lubricators have heaters incorporated in them, and they are more oblivious to cold than any man. They do not solidify in winter, therefore, and they do not overfeed in summer.

The only way to avoid dust clogging was to place the oil in a solid box free from the working parts. This principle, as soon as discovered, was applied in the most advanced type of pumps. In this way it was made absolutely impossible for flying dust and grit to get into the oil and be carried to the bearings.

The working parts should be as simple as possible and they must be easily reached and repaired. One of the best models has a one-piece valve which eliminates practically all troubles, for it is obviously impossible for a solid casting to get out of order. All the working parts of this model are on the outside of the oil reservoir which probably accounts for the absence of repair bills for continuous service.

# Process and Apparatus for Increasing Production in Steel Manufacture

### Showing Difficulties That Crop Out in Present Open Hearth Practice and How They Can Be Overcome With Increased Production in a New Process—Based on Better Method of Pouring Steel.

By **ADOLPH A. RACKOFF.**

THE first part of my paper is a review. Though the present system of steel production is universally known, still it may not be out of line to review the making of steels under the present conditions, and under the present system. This will also enable us to carry a clearer understanding in the reading of the second part of this paper.

## Classification

The making of steel can be classified in two stages; the preparation of solids to be melted into liquids, and the melted liquid to become solids again, termed "Steel". The first stage is done in specially designed furnaces, as "Open Hearth Furnace", "Blast Furnace" and "Electric Furnace". The second stage begins when the metal is poured in the ingot molds, rolled and sheared into billets and shipped as raw material for various purposes. The preparation for the first stage gives to the steel the chemical properties while in liquid state, and through the various processes in the second stage, it receives the physical properties, classifying it for various grades and for various purposes. Some steel plants turn out a certain grade of steel, while other plants carry greater burdens for making steels for all purposes of all grades on a very large scale.

## Furnace

The melting takes place in the furnace under the high blast of gas and it is drained into ladles when the liquid shows the proper test for making that grade of steel called for by the market.

## Ladle

The molten metal is drained from the furnace through a trough into the ladle. The ladle rests on solid supports on the floor at the "Open Hearth" plants. The ladles vary in size and are very massive, specially designed for that purpose. These ladles are lifted form their supports, at the "Open Hearth" plants, by

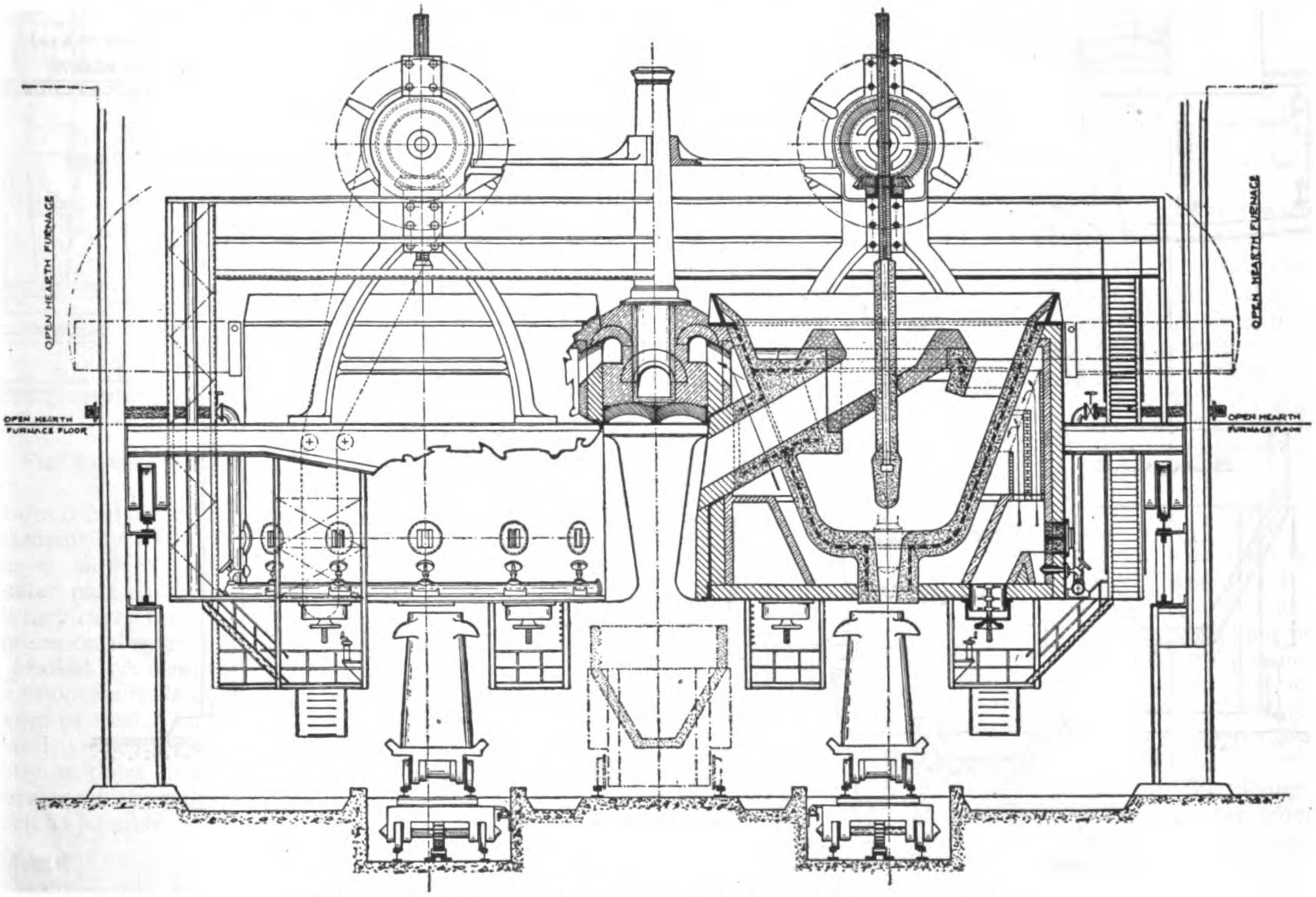


Fig. 1—Apparatus for a double row open hearth furnace p lant.

pecially designed cranes having massive hooks to lift and carry these enormous loads to the opposite side of the furnace for emptying it into the ingot molds. The ingot mold chills the metal and solidifies it through squeezing the webbing combination of the so-called "steel". The ladle is next to the furnace, which is the "melting pot" of the "Open Hearth" process, as all impurities are gathered in the ladle from the drained furnace.

## Ingots

From the ladle and while the molten metal is still

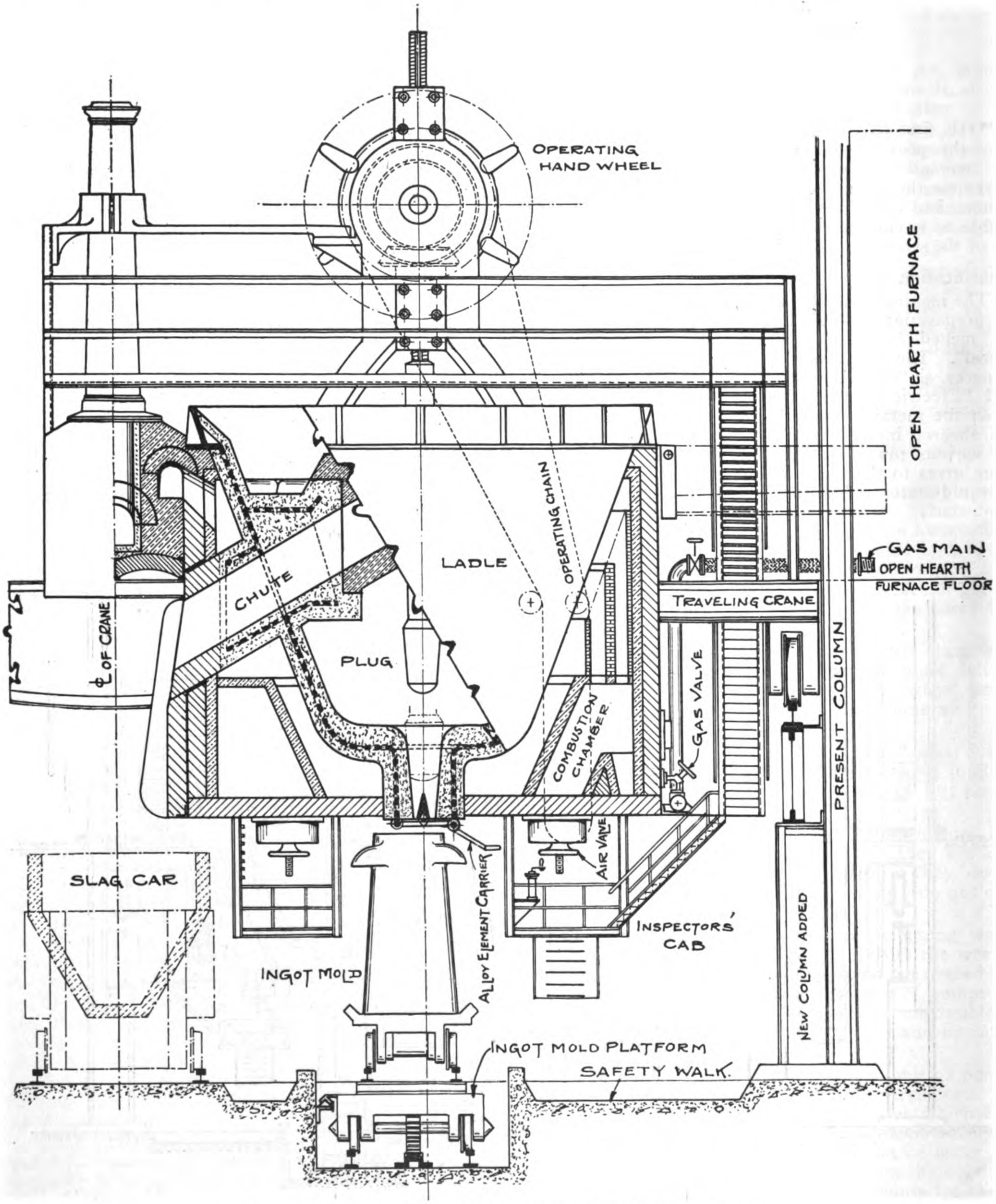


Fig. 2—Apparatus for single row open hearth furnace plant.

at pouring stage, the metal is poured into molds. The molds line up with the ladle drain plug that stops the flow when the mold is filled. These ingot molds are again the "Melting Pot" of all the impurities that fell into them from the ladle while pouring the hot metal. When the ingot has "webbed" itself to become a solid mass, it is stripped on its road to the soaking pit. After receiving the "sweating bath" which gives to the outer skin of the steel a chance to become pliable again it is rolled in the blooming mill.

### Blooming Mill.

At the blooming mill the ingots are rolled to certain sizes and are sheared to certain lengths and called billets, our term for "raw material" of the steel market.

### Rolling.

The rolling, though it is considered to be part of the product finishing, however, must be classified as a treatment by itself, for the simple reason that we need greater skill at the mill rolling than elsewhere. The greater part of the steel making falls upon these men, for they carry the real burden of the production, and for this reason they are the ones subject either to be blamed or praised. A competent person in the steel industry can tell at once who is to be blamed for the defects in certain grades of steel. Though considering the metal very hard to roll, yet the "wild pass" under the mill rolls is very costly at times in all ways concerned. It is up to the operator of the pulpit to watch and to avoid defects as much as possible.

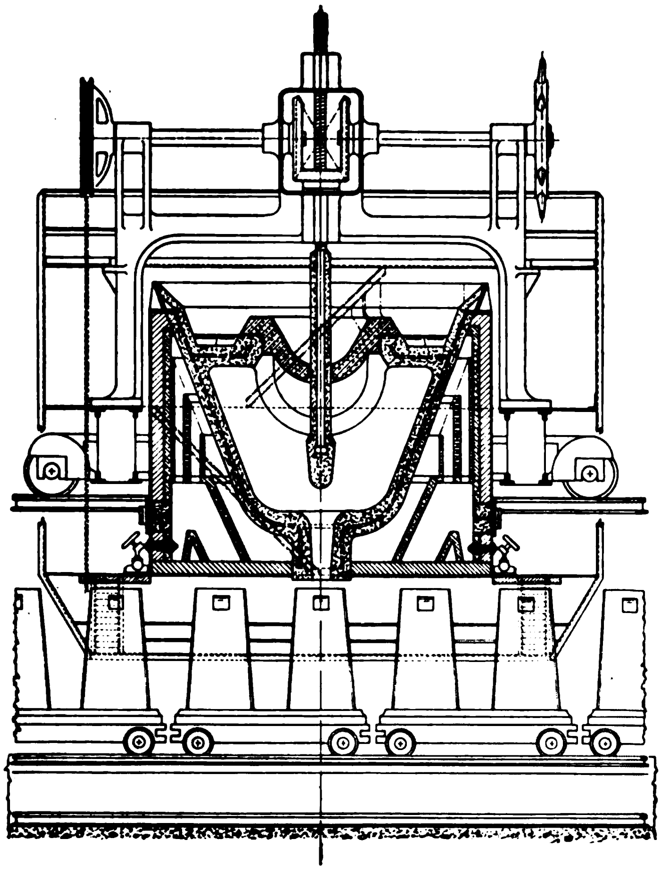


Fig. 3—Apparatus and ingot molds at pouring stage.

### Defects.

While rolling the ingot stock in the blooming mill, we meet many losses in steel making. At this stage the steel proves its gain value; also at the same stage it may be termed "scrap." At times it may be the fault of the pouring, and at times it may be the fault of the roller. In all probabilities it carries the signs of the latest two defects. The tearing in the stock that comes from the internal blistering of the foreign matter that lay hidden at certain depths in the mold; and it is also due to the sudden change of hardness in surface chilling, as the ingot is harder at the shell than at the center; also, it is due to the rough treatment of the mill by the manipulator controlled from the pulpit. These defects carry mere luck in the manufacture of steel and we are with the optimistic hopes that what we do not know will not hurt us, meaning the blindness of such results. By rolling the ingots receive the "seam defects", and that can be termed as "skin disease", showing surface cracks that must be remedied. Chipping is the only remedy for it, as certain grades of steel will not weld at the proper welding heat. As such cracks are usually very long and deep, it takes considerable time to remove them. Besides, it is costly as it causes many delays in production. Scrapping such steel will not bring any returns. Many steels carry expensive properties which make the steel very valuable..

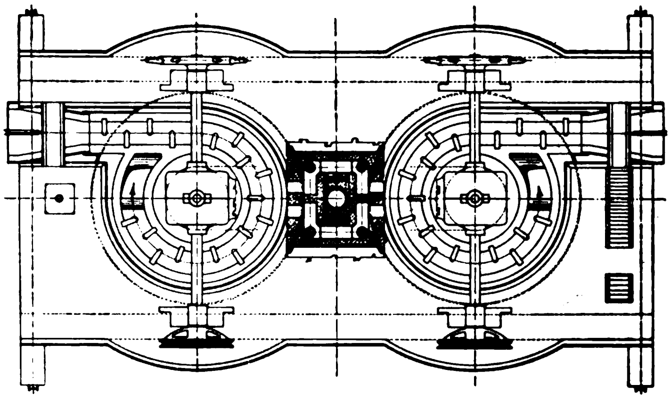


Fig. 4—Plan showing flowing of metal in the purifying stage.

Though the rolling brings out the defects of our production, there is no better treatment thus far for steel than rolling. We surely satisfy ourselves in making new machinery or devices that will help us in getting rid of the defects mentioned; but we find that there is no means that will eliminate the rolls or the rolling; also, we still consider rolling very valuable in steel making, as it is considered to be the "tell tale" of the steel making at the second stage.

### Conditions.

Under present conditions we find the operations in producing steel very expensive. If money would be the only "hold back", we would perhaps find means to make up such a difference, but the shortage of labor cannot be replaced by money, and in the meantime we are producing less steel at a costly price. We surely have no means under the present system of making steel by the open hearth process, in finding a remedy, unless we change the system; not only to save few men, but to save material that is termed "scrap" or waste. The change, though being "radical" as some may term it, is far from being such. A change in anything must bring results for a betterment, even if it is costly from the start.

At times we do consider a change practical, even when things bring good results. The practicability lies in making a forward step towards greater developments.

Upon such a change I am dealing in the next part.

### Summary.

The above mentioned shows the making of steel under conditions that exist at present in the "open hearth" process. The disadvantage exists not only in the handling of the product, but it forms a question of how to save the many operations which are now in use. It shows the magnitude of the ladles and the labor invested to get results. It shows the time required to empty the ladles which are only carriers for the molten metal. It shows the cooling of the metal in the molds, while poured at the center and giving a large proportion of "pipe" to the ingots. This may be due to the ingot mold shape disadvantages, or because the pouring at the center of mold does not fulfill the requirements of same. The defects and expenditures in making steel under present conditions carry warning for a close study, either for improvement, or change. The gain in saving of space and time were omitted when the present principle was developed to this stage.

However, this does not include the certain percentage of laborers that are either crippled for life and must depend upon compensation, which is a heavy burden to the industry, or are wasting their time in the hospitals suffering from injuries that the "safety first" idea cannot control and cannot protect, but it is a well known fact that the steel industries carry a large overhead expense to meet such conditions.

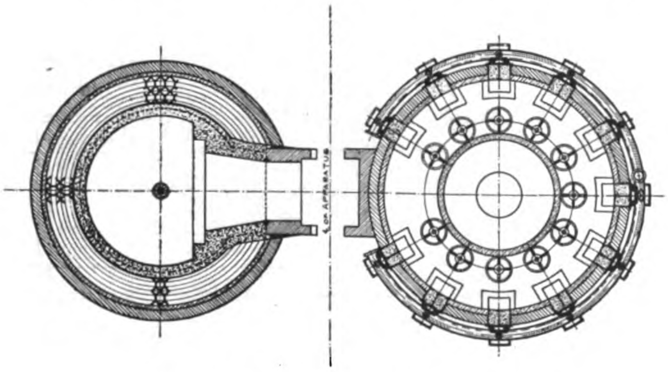


Fig. 5—Generators and burners.

### Introduction of Second Part.

To consider the importance of homogeneity in steel, we must not forget the importance of purity of the metals. It is of course, the metal that carries its good name; but as a good name must protect its own dignity, so let steel be whatever people can make out of it, as long as it is pure, or even so pure that it can protect its own trademark. The purity of steel is forging ahead for we have realized how different the grades of steel are, though molten from the same furnace and same blast, carried by same ladle and formed by same mold and rolled by the same mill. The impurities can not be avoided, as there is nŏ means of avoiding it. The metal falling down from the furnace into the ladle, carries with it all obstacles down to the bottom of the ladle. There they are kept down even in a molten state. The heavy or light particles of slag cannot come up to the top, because there is no stirring; the heavy splash keeps them down, and after pouring they find no path to get up; hence, they wait for the plug to open the path for them. These particles enter the molds with no resistance, and there they remain again on the bottom and chill. These obstacles are the enemies in steel making. They at times show failures in the very best steel and the elimination of such enemies is impossible, unless a new system of dealing with them, in trapping them at the right spot, will bring success. These particles while in the ingot molds, become solid, and after being rolled come up to the surface and show cracks, or seams. They form blowholes and gas holes. At times such defects come direct from the "crop end" in splitting, and the splitting, at times, shows throughout the entire length of the ingot. It is, perhaps, good luck that such defects are exposed in the mills by rolling, for otherwise we would be in need of taking tests of every foot of steel we would make. Of course, we do not depend upon luck and we try to look after these defects as much as possible.

### Principle.

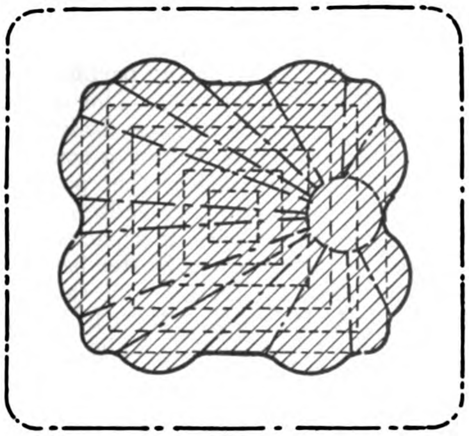
Considering the change that takes place in the furnace when the metal melts, also realizing the importance of purity of such a molten liquid, which must become a solid mass again, carrying in it the very best of the steel product, there can be no better satisfaction to the steel maker than getting a clean, pure molten liquid when possible. The possibility lies not in melting, but in draining. As soon as the metal is ready for pouring, we must consider pouring the main issue and the furnace must come next. As soon as the metal is ready for the ladle, the ladle must be the main issue and the pouring must come next to the ingot molds. These stages, when carried in mind, simplify the making of steel under a purer principle. The principle lies, firstly, how to get the liquid out of the furnace; and secondly, how clean the liquid can be for the ladle. When this is done properly, there must be accommodations to purify the liquid still further, while the metal is poured into the molds. Upon such stages my idea is based. It is a process for production in steel manufacture with obtainable results.

### Ladle.

While the ladle has a stage to convey the liquid metal from the furnace into the molds, its role is very valuable in steel making for it carries a double purpose. Firstly, to clean up the pouring metal; and secondly, to diminish as much as possible the volume of metal that is termed "slag". This type of a ladle is not of a "pot shape" with a liner, for it must be a strainer, or a funnel to do its purpose. Furthermore, it must not only purify the liquid, but must also keep the same liquid at the same temperature, when it leaves the furnace bath, so the metal reaching the mold has then the stage of solidification. I have therefore, developed a new ladle, "strainer", in which when the metal leaves the furnace it passes through the process of purification, and all light or foreign particles can either be checked from flowing into mold, or "raked off" at the top of the ladle. The ladle is a part of the furnace that is carried by the crane. The ladle has a perforated metal heart covered from both sides with fire clay and protected from getting in touch with the flowing liquid steel. At the bottom is the drain hold for pouring the metal into molds. Though the crane carries the ladle, it is at a standstill when the metal pours from the furnace and passes through the ladle into the ingot molds.

The ingot molds rest upon carriages and same carriages stand still on a movable platform that moves outward when an ingot mold is filled. The platform is constantly connected to the driving arrangement, so there should be no jerking or knocking in moving the ingot molds from underneath the ladle.

The crane is built so that two ladles are carried opposite each other and are connected by a platform which is in line with the "Open Hearth" furnace floor. When so arranged, the same crane can operate two furnaces simultaneously. It is also designed that an operator with helper can perform their duty in getting results as outlined by the department superintendent.



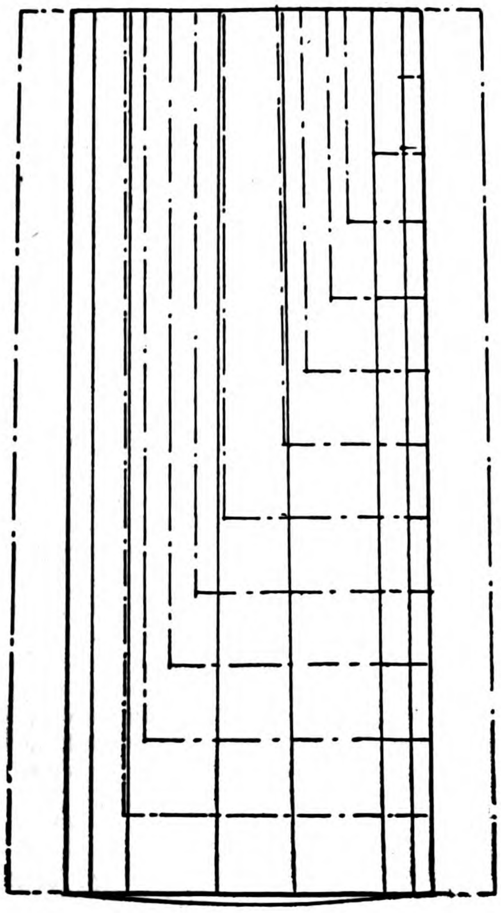


Fig. 6—Diagram of ingot chilling.

In the center of the ladle is the plug that stops the flow of the metal from getting into the mold when the latter is filled. The metal still pours from the furnace into the ladle until the next ingot mold is in line with the ladle and the plug is lifted following same operation until the furnace is emptied. The ladle in this system carries great value in steel making. Its value has a double purpose, for which it is worth adopting. First, it is a mixing device that will aid in forming a stream of pure metal for the molds, as explained. Second, it will reduce the slag to the very minimum. The formation of slag and waste do not exist in this process. Furthermore, the last ingots may be classified for inspection after rolling and they will tell the tale of the product that may lead us to still greater developments in steel manufacture.

### Ingot Molds.

The molds in this principle are corrugated in shape, and are rectangular in form. This type will carry double purpose. First, it will aid the rolling as the surface contact will be less than in the present shape of molds; second, the elongation will increase quicker. The pouring of the metal from the ladle into the mold in this process is done at the "offset" of the mold. This again ought to aid the chilling of the metal on all sides and influence the forming of "the pipe" at one side of the mold instead of at the center of the mold. Such a principle carries not only the elimination of "pipe" but gives the ingots the proper chilling, as the metal squeezes itself to web the combination of its composition towards the upward end of mold, instead of pressing the metal through chilling towards the center with the allowance of a long "pipe" unchilled; besides, while the ingot molds will be corrugated, the surface around the pipe at point of flowing is diminished, and that will help the chilling considerably. It will also aid in getting the forging process in ingots through rolling, for the corrugated side at the pouring will be the softest and the only side that will yield to rolling from the first pass, but giving resistance to the rolls in other passes in the rolling process, as the ingot is getting tougher towards the center, though this ingot is being lengthened.

### Pouring.

The metal while leaving the furnace and following the path towards the molds will pass a purifying system that will stop the heavy particles of the liquid from reaching the ingot molds. This path will be open to the operator and he can have full control over that operation, for the flowing metal through the trough will be shallow and solid particles that form slag will be seen, stopped at the scrubbers and raked off into the chute.

### Trough and Liner.

The trough that connects the furnace with the ladle will be part of the ladle. Its nature will be to break up the flowing metal and to stop the heavy particles from getting into the ingot molds. The metal has a horizontal flow from the "Open Hearth" furnace into the ladle and has a vertical flow from the trough to the bottom of the ladle that stirs the metal in its course of falling. The space between the trough and the plug surface forms the reservoir for the metal that has been cleaned before reaching the plug opening at the bottom of the ladle.

### Slag Waste.

The slag waste in this principle will be a very small portion of the melt. The slag having no chance to form as a liquid will always be at the melting temperature at the trough of the ladle. As there will be no time allowed for the metal to chill, the flow of such a stream will be continuous. The slag that will gather in the course of the flow at the ladle will be held or trapped at its formation while leaving the open hearth furnace and will be "raked off" to the chute. The slag will be pushed off and thrown in a bucket that stands on the ingot mold floor below the crane. The operator who is watching the flowing metal is responsible for the pouring and it is up to him to see that no slag is formed at this stage.

### Equipment.

The equipment for this proposed principle carries great importance in the steel manufacture. Its purpose is to have all the molten metal, after being melted in the furnace, brought back again into solids with the minimum of "slag." It must fulfill the intended purpose in increasing production and decreasing labor, in giving to the steel world the homogeneouty of metal through pouring. The pouring starts when the molten metal is ready for draining from the furnace continuing until same metal is drained through the ladle into the ingot molds. This equipment must serve in having the metal reach every channel that makes the pouring valuable.

### The Crane.

The crane is of an ordinary design for holding the floors and the furnaces that carry the ladles. The furnace floor will form a bridge for the operators to cross over from one side to the other. The same floor will line up with "Open Hearth" furnace floor. The crane will accommodate two ladles parallel to each other and divide the floor in compartments so each ladle can be taken care of independently, through the draining may be simultaneously. The crane floor will be above the ingot mold floor, allowing the clearing of the ingot molds with their equipment. The crane is holding the ladles loose, so they can be picked up with no loss of time. The crane consists of three floors; the operator's floor, the girder's floor, and the inspector's floor. The inspector's floor carries a rung ladder that gives an exit to the ingot mold floor. The inspector's floor allows the ingot mold to pass through, however, it is fitted with a sliding platform so the entire floor space can be used for adjusting the air flues and for checking the gas valves. The gas valves will also be controlled from the operator's floor. The girder's floor will carry all driving apparatus, and the stand for the plug lift. On the left side of the crane will be a "sliding down" pole.

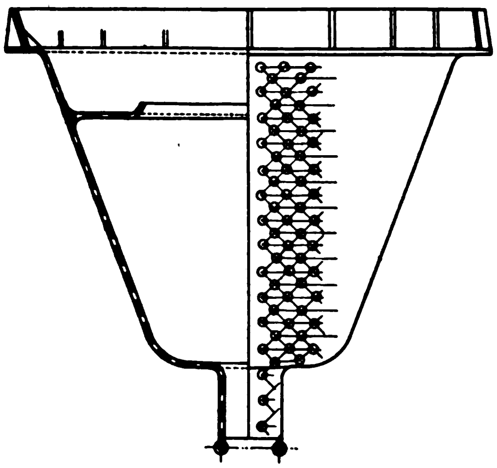


Fig. 7—Ladle core.

### Ladle Proper.

The body or core of the ladle will be perforated so as to allow the brickwork to be united with the body. The ladle will be of a funnel shape, having a brim at the upper portion of the ladle. The surface of this trough will be in staggered projections so as to give the metal a scrubbing, or trapping the heavy particles that are carried in the metal in a molten state. This trough will connect with "Open Hearth" furnace drain hole and the ingot molds. The trough is making a complete circle at that portion of the ladle, and at that point the flowing metal takes the vertical drop, or falls to the bottom of the ladle. This gives a reservoir capacity for the metal when the ingot molds are shifted after being filled. The trough also broadens its surface and carries a proportional incline from the "Open Hearth" furnace to the vertical fall of the metal into the ladle, proper.

### Heating.

The ladle, though considered a separate part of the furnace that holds same ladle, is however, a component of the furnace and together makes a complete unit of the ladle in this principle. The ladle will rest upon a bearing of the furnace, and will receive the generating heat from furnace so as to be in a hot blast, while the pouring from the "Open Hearth" is taking place. The gas blast for heating the ladle will have a connection to the main gas line. The ladle while resting upon the structure of the furnace, will be easily lifted from its seat for relining purposes.

### The Chute.

The chute is part of the ladle and is concentric with the trough at its upper end. It consists of a mouth piece that can be taken out when relining is necessary.

### Plug.

The plug is of a simple design and is operated from any floor either by hand wheel or chain. The lifting is done by gear arrangement that keeps the plug moving up or down in bearings without turning.

### Ingot Mold Platforms.

The ingot mold floor is excavated to allow the ingots to pass under the ladle with as much clearance as possible. The ingot molds will be brought to the furnaces in the usual manner and before reaching the furnace plant they will run over platforms that slide in floor trenches and bring them to the proper place so that the first ingot mold will go outward when it is filled, bringing to the ladle the next empty mold. There should be enough ingot molds on the platform for one heat. The platform will be operated by a motor directly connected to platform frame. The operation of the platform is very simple and its construction is likewise. There will be "one way road" at the furnaces, which allows an endless road in supplying ingot molds for the pouring.

### Slag Car.

Slag car will be of an ordinary design for its purpose, and it will be used for bringing the "slag" or "waste" to the furnaces for remelting.

### Increased Production.

The increase in production is seen at once by the new system. This system will bring a decrease in labor of about 60 per cent. The increase in production will be obtained by the following:

1. The number of furnaces can be doubled.
2. Track accommodations at the furnace can be placed with a supply of ingot molds right at the furnaces.
3. The labor used at present for cleaning and watching will be utilized for actual production.
4. The floor of the entire "Open Hearth" plant will be level, no dugouts for slag cars or ladles. It will form a sanitary plant of a modern plan.
5. There will be no loss of time in conveying the poured metal from one place to another; the pouring in this principle is direct.
6. While the ladle is part of the crane, there is no need for chain-men or hook-men. A craneman with a helper can perform all the work necessary to get out a "melt".
7. The yard will have more empty space for storage, tracks and traffic.
8. This principle is more logical in getting results than the present system.
9. The repairing will be diminished to a minimum. (a) No liners; (b) No bricklayers; (d) No idle ladles in repairs; (e) No idle investment amounting to millions on the upkeep of the repairing.
10. The production will be termed "controlled" for it will be within the reach of the operator to check any trouble by marking the ingot molds "for inspection" or "remelt" or other signs that may control caution or attention.
11. Under this process we could stop the waste of labor in avoiding scrap after many operations were performed as it is done in the present system. There will be one road in saving, that is, to economize, which is done by watching the flow of metal from the furnace into ingot molds; this being done by new process and apparatus.
12. There may be new market fields open for our first grade steels. Second grade steels that may be termed such through a system of great watching and thorough inspection can be had in this new process of making steels by the "Open Hearth" process.
13. This apparatus can be used for any type of open hearth furnace, either stationary or tilting.
14. This process furnishes the same heat and same melt for various grades of steel right at the pouring course for any desired shipping daily tonnage.
15. The change for installing this apparatus is gradual and it will not interfere with the present production.
16. Under this process there will be the minimum of losses in accident and injury to the workmen. The overhead charges for such an upkeep will be of no importance. The trained man will have the full benefit, as he will work under the most sanitary and safe conditions of a modern plan in steel manufacture.

# Heat Supplied to the Blast Furnace

## Variations in the Heat Supplied and Their Effects on the Fuel Consumption—Dry Blast Is Not a Paying Investment in Countries With Low Average Absolute Moisture.

By W. W. HOLLINGS.

IT has not infrequently been observed that, when some notable addition has been made in the supply of heat to the blast furnace, the resulting economy in fuel has exceeded the theoretical fuel equivalent of the heat actually added. Two prominent examples of this discrepancy were afforded by the introduction of the hot-blast by Neilson and of the dry-blast by Gayley.

In his "Chemical Phenomena of Iron Smelting," in the section "On the Theory of the Hot Blast," the late Sir I. Lowthian Bell quotes a specific instance where an increase in the temperature of the air from 60 to 450 degrees F. reduced the coke consumption from 60 cwts to 38 cwts per ton of pig iron, a saving of 22 cwts, or 36.66 per cent. Now, per ton unit of carbon burnt in the furnace, the above increase in the blast temperature would mean the addition of, roughly, 300 cals to the hearth, an amount of heat equivalent to 2.43 cwts of carbon burnt to CO before the tuyeres, or a saving of only 12.15 per cent. Similarly, from the account given by Mr. Gayley of his original application of the dry-blast, it would appear that by drying the air—and incidentally increasing its temperature from 382 to 465 degrees C.—he reduced his coke consumption from 2147 lbs. per ton of pig iron to 1726 lbs., a saving of 421 lbs. or 19.61 per cent, whereas on the basis of any theory hitherto advanced the maximum saving possible was between 12 and 13 per cent.

When Mr. Gayley first published his results in the autumn of 1904, in common with many others the Brymbo Steel Company was much attracted by the seeming possibility of a considerable reduction in fuel consumption. Determinations taken over an extended period had shown that the moisture in the atmosphere at Brymbo ran on an average just over 3 grains per cubic foot, and no difficulty was anticipated in being able to reduce this to the region of 1 grain. If Mr. Gayley was able to obtain a saving of practically 20 per cent in his fuel consumption by reducing the moisture in his blast from 5.66 grains to 1.75 grains per cubic foot, or by 3.9 grains per cubic foot, it was assumed that an economy of not less than 10 per cent should be attainable by a reduction of 2 grains per cubic foot.

The matter was temporarily left in abeyance, but as time went on and confirmatory reports were received from various sources it was decided, in 1909, to proceed with the erection of a plant for drying the air. The method adopted finally was that of freezing out the moisture by means of the ammonia absorption process. The necessary machinery was supplied by Messrs. Ransome & Rapier of Ipswich, and as far as this part of the process was concerned there was no cause for complaint. From the moment of starting up, the plant was all that could be desired for economical and efficient working; in fact, the cost of operating came out lower than had been figured. Unfortunately, the practical results obtained from its application fell very far short of the economy hoped for, the actual saving being only 3.34 per cent in place of the 10 per cent anticipated.

In view of the brilliant results obtained by Mr. Gayley, this wide difference appeared to call for some explanation, and the search for such an explanation resulted in

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Paper read before British Iron and Steel Institute, autumn meeting.

the construction of the theory which is advanced in this paper. This theory accounts satisfactorily for the great saving attained on the introduction of the hot-blast by Neilson and also for that obtained by Mr. Gayley with his dry-blast, while at the same time reconciling the wide difference in the results obtained by Mr. Gayley and the Brymbo Steel Company.

If the blast furnace be regarded solely as a medium for the production and absorption of heat, the heat produced will be made up of—

a. The heat brought in by the blast;
b. that developed by the combustion of the fuel;
c. that evolved in the formation of the slag and iron compounds;

while the heat absorbed, including losses by radiation and cooling water, will be the heat developed, less that carried away in the furnace gases.

It is common knowledge that in a furnace working on a given burden, a certain amount of heat will be necessary for the production of a ton of pig iron of a given grade, and that of this total heat a certain proportion will be absorbed in the furnace (including that necessary to satisfy the losses by radiation, cooling water, etc.) and a certain proportion will escape in the exit gases. If further heat be added to the furnace, the amount of fuel necessary to produce the total heat required for the production of a ton of metal of the same grade must be reduced.

Now, in the reduction of the iron ore used in making a ton of pig iron from a given burden, the amount of oxygen liberated from the ore is approximately constant, varying only very slightly with the proportion of impurities reduced with the iron, so that, even though the quantity of fuel per ton of pig iron may vary, the amount of carbon oxidized to $CO_2$ by the reduction of the ore remains approximately the same per unit of product. If the blast temperature be raised, not only is less fuel required to develop the same amount of heat as before, but in diminishing the quantity of fuel the ratio $CO_2 : CO$ in the gases is increased, resulting in a further addition of heat through the improved calorific efficiency of the carbon burnt. Similarly, this diminution influences the proportion of heat obtained from the formation of the slag and iron compounds per unit carbon burnt, increasing the supply from this source also.

Furthermore, by varying the amount of heat brought in by the blast, the number of calories conveyed to the burden per unit weight of the ascending gases is also changed, the absorption by the burden appearing to approximate to the formula—

$$a_2 = a\sqrt{\frac{c_2w}{cw_2}}$$

where a, c, and w represent respectively the amount of heat absorbed, the number of calories developed, and the weight of gases evolved per unit carbon burnt before the change, and $a_2$, $c_2$, and $w_2$ the same after the change. This change in the absorption of heat by the furnace takes place at the expense of the furnace gases, which are correspondingly, but inversely, varied in temperature.

For example, let it be assumed that a unit of pig iron of a certain grade and from a given burden requires a unit of carbon for its production, and that the thermal ratio $CO : CO_2 = 0.25 : 0.75$ in the gases (by thermal ratio is meant the proportion $CO_2$ to CO actually participating in the production of heat). The unit of carbon here produces 3810 cals. If 500 cals be brought in by the air and 100 cals evolved in the formation of the slag and iron compounds, the total heat developed per unit carbon burnt in the furnace will be 4410 cals, and if 550 cals be carried away in the furnace gases the amount of heat "absorbed" by the furnace is 3860 cals.

Should the temperature of the blast be raised sufficiently to increase the supply of heat from this source to 700 cals—an addition of 200 cals—the amount of carbon required to produce the necessary heat for the production of the unit of pig iron, assuming the ratio $CO_2 : CO$ to remain constant, becomes—

$$1.00 \times \frac{4410}{4610} = 0.9566;$$

but since the amount of oxygen liberated in the reduction of the pig iron is the same as before, the thermal proportion $CO_2 : CO$ becomes $0.25 : 0.7066$ and the unit of carbon produces 2864 cals, an increase of 54 cals. Similarly, the heat from the slag and iron compounds will be $\frac{100.00}{0.9566}$ or 104 cals, a gain of 4 cals, making the total from these two sources 58 cals per unit carbon burnt in furnace.

Assuming for the moment that the weight of gases per unit carbon burnt in the furnace remains constant, the heat absorbed will be—

$$3860\sqrt{\frac{4610}{4410}} = 3946 \text{ cals},$$

an increase of 86 cals, involving a diminution in the temperature of the gases at their exit.

Thus the increment of heat in the furnace per unit carbon burnt from the improved chemical and physical efficiency directly resulting from the addition of 200 cals, amounts to 144 cals. If these 200 cals induce an internal augmentation of 144 cals, these 144 cals will in their turn be responsible for a further addition of $\frac{144}{200}$ of 144, and so on. Therefore:

"Any variation in the amount of heat supplied to the blast furnace involves a secondary and complementary series of changes in the amount of heat produced and absorbed internally; and the proportion borne to the initial variation by its complementary internal change constitutes the ratio of an infinite geometric series of which the primary variation itself forms the first term."

If $a$ be taken to represent the initial variation and $r$ the proportion borne to it by its complementary internal change, the total variation involved will amount to the *sum of the series* $a + ar + ar^2 +$, etc., to infinity; or $\frac{a}{1-r}$.

In the example under consideration the values for $a$ and $r$ respectively will be 200 and 0.72; $\frac{a}{1-r}$ will then amount to 714.3 cals, and this will be the ultimate calorific effect on the furnace for that burden by the addition of 200 cals per unit of carbon burnt, and the amount of carbon required per unit of pig iron will be—

$$1.00 \times \frac{4410}{5114.3} = 0.8623.$$

It will be as well to note here that in dealing with dry-blast there is a change in the proportion of $N_2$ per unit of air blown when compared with normal blast, and consequently a change in the weight of gas formed per unit carbon burnt at tuyeres. The proportional relationship $a : ar$ and $ar : ar^2$ will be thus effected, and it becomes necessary to sum the series in two steps. The value for the internal change complementary to the initial variation should be first ascertained, and the series summed from this point on. In the above example 0.9566 becomes the fuel base for the series, and 144 the initial variation.

If the above theory—which was first evolved some six years ago, but has been held up until now principally for reasons connected with the war—be applied in detail to the figures of Mr. Gayley's original trial it will be found that, for a reduction of the moisture in the air blown from 5.66 grains to 1.75 grains per cubic foot, and an increase in the blast temperature from 362 degrees to 465 degrees C., the theoretical consumption corresponding to the initial figure of 2147 lbs. of coke per ton of pig iron works out at 1675 lbs., showing a saving of 21.92 per cent. During the trial in question Mr. Gayley's actual consumption varied between 1462 lbs. and 1952 lbs., with a mean of 1726 lbs. for the whole period of the trial—an economy of 19.61 per cent. The average temperature of the exit gases under dry-blast was given as 191 degrees C. against 282 degrees C. when working with normal blast.

For the purpose of making a theoretical estimate of the temperature of the outgoing gases corresponding with the consumption of 1675 lbs., the losses through tuyere and cooling water had to be included under one head with the radiation losses, as no separate figures were obtainable for these items. This obviously introduces a source of error, as there is no proportional relationship connecting these three sources of loss. It was assumed that the combined loss for these three items followed the formula for heat absorption previously given. The temperature obtained for the exit gases to correspond with the consumption of 1675 lbs. of coke was, on this assumption, 154 degrees C., and that for 1726 lbs. was 169 degrees C. in place of the 191 degrees C. observed in practice.

Of the 21.92 per cent saving in fuel obtained theoretically, 11.34 per cent was shown to be due to the actual drying of the blast and 10.55 per cent to its increase in temperature from 382 degrees to 465 degrees C. In the case of Brymbo, the theoretical saving obtained for a reduction in the moisture in the blast from 3.1 grains to 1.3 grains per cubic foot amounted to only 2.18 per cent as against 3.34 per cent obtained in practice. In this case the drying of the air was slightly offset by a diminution in the blast temperature from 632 degrees to 621 degrees C.

Owing to the lack of information respecting the amount of heat carried away in the tuyere water, the heat delivered to the furnace by the blast had to be taken at the temperature of the "bustle," whereas it ought to have been somewhat less than this. As the temperatures of the dry and normal air differed somewhat in both cases this introduced a small error. In the case of Mr. Gayley, the dry-blast being at a considerably higher temperature than the normal blast, there would be a slightly greater loss through tuyere water, diminishing somewhat the theoretically calculated saving. With Brymbo, on the other hand, the temperature of the dry air was slightly lower. In both cases, had it been possible to include tuyere water losses, the result would have been to bring the theoretical results even more nearly into line with the practical.

Before the theory which has been advanced in this paper could be applied practically to any specific case, it was necessary to assume the existence of some stable relationship between the burden working at its maximum efficiency and the gases given off during its reduction. It was also essential to have an absolutely representative analysis of these gases, in order to establish accurately the initial calorific value of the unit of carbon burnt. In this respect it was noted that the $CO_2$ and CO contents of the furnace gases while working on normal blast were given by Mr. Gayley as 13 per cent and 22.3 per cent by volume respectively. These figures cannot be representative, for if as high a figure as 4 per cent be assumed for the $H_2$ in order to reduce as far as possible the proportion of $N_2$, and the gases be then placed on a basis of atmospheric $N_2$ per unit carbon burnt at tuyeres, it will be found that the amount of carbon other than that due to combustion at the tuyeres will not be sufficient to satisfy the proportion known to have been introduced by the limestone alone. For this reason it was necessary to reject the above values for $CO_2$ and CO and to build up a gas from the burden in accordance with some given relationship. As whatever goes into the furnace must come out, either in the slag and pig iron or in the gases, such a relationship should be possible of demonstration if a sufficiently comprehensive and accurate research be carried out.

An investigation on a straight haematite ore burden, owing to its simplicity, appeared to offer the most promising field. The author was fortunate enough to have before him the results of a very remarkable trial on such a burden carried through on the Isabella furnaces in 1909, by their superintendent, Mr. Maccoun, with a view to establishing a heat balance for the furnace.

The results were embodied in a treatise entitled "Blast Furnace Advancement," and read before the American Iron and Steel Institute in May, 1915. It will be noted that the research was on the same furnaces as those on which Mr. Gayley carried out his dry-blast trials.

The root idea assumed by the author of the present paper, and applied subsequently in making the Gayley and Brymbo calculations, was that the carbon burnt above tuyeres was not a capricious quantity, but was made up of the small proportion required for the "direct" reduction of the silicon and phosphorus and a balance consisting of the amount necessary to satisfy the equilibrium $\frac{CO_2}{CO}$ corresponding to the mean temperature of the zone of dissociation of the limestone. On this assumption the quantity of carbon burnt above tuyeres for a given burden remains approximately constant, and its proportion to the total carbon burnt increases as the fuel consumption per ton of pig iron diminishes. When investigating Mr. Maccoun's figures it was found that if all the iron and manganese were held to exist in the ore in the form of the highest oxides, there was an excess shown in the amount of $O_2$, from sources other than the blast, over that actually present in the gases. The whole of the manganese and a small percentage of the iron was therefore held to exist in the ore in the form of the lower oxide in complex ferro and mangano-aluminum-silicate minerals, though possibly a small amount of this ferrous iron may be due to the reaction $FeS + CaO + C = Fe + CaS + CO$.

When dealing subsequently with Mr. Gayley's figures it was interesting in this case, likewise, to note that, unless the whole of the manganese and about 2.5 per cent of the iron were held to exist as lower oxides, it would be impossible to devise a pig iron having a sufficiently low "oxygen equivalent" to correspond with both the fuel consumption and the composition of the burden. These complex silicates of manganese and iron were assumed to be reducible only on their composition being broken up on "slagging" and the equivalent iron and manganese were added to the phosphorus and silicon as substances obtained by direct reduction, i.e., by means of carbon direct or by CO at a temperature superior to 1000 degrees C.

If the $N_2$ contained in the coke, and the exact amount of moisture contained in the blast be known, the constituents of the furnace gases can be placed on a basis of atmospheric $N_2$ per unit carbon burnt at tuyeres, and so classified proportionally as products of combustion at tuyeres, and products derived from the reduction process in the furnace. This method was employed in dealing with Maccoun's figures. It was then noticed that the proportional relationship between the oxygen extracted from the ore and the carbon burnt at tuyeres could be accurately established. If the analysis of the pig iron be known, its "oxygen equivalent," or the amount of oxygen extracted from the ore in the production of a unit of pig iron, is also known. If this latter figure be divided by the amount of oxygen extracted from the ore per unit of carbon burnt in the furnace, the amount of carbon necessary to produce a unit of pig iron will be the result. In Mr. Maccoun's trials the actual amount of coke consumed per ton of pig iron made was 1901.6 lbs. The amount obtained by estimation from the gases by the above-mentioned method was 1901.4 lbs.

The author is conscious that no law can be laid down as the result of a single trial however completely and accurately carried out. The figures derived from Mr. Maccoun's research, however, are in such close agreement with the hypothetical relationship between burden, gases, and fuel as imagined by him, that he ventured to assume this relationship as fact when it subsequently became necessary to build up a gas on dealing with the Gayley and Brymbo trials. Much work would be necessary before it could be established whether or not this relationship holds true for all burdens. Mr. Maccoun's figures showed that the amount of carbon consumed by "direct" action only amounted to 40 lbs. on a total of 1648 lbs. carbon burnt in furnace, or slightly less than 2.5 per cent, representing about 1 per cent by volume in his furnace gases, so that very accurate sampling and analysis would be required to detect any slight variations in the total amount of "direct" carbon. A continuous 24-hour sample treated on the principle of organic analysis, and in which the residual $N_2$ would be estimated by measurement, would seem to promise the best results. In dealing with the figures from Mr. Maccoun's research the writer ventured to differ from the treatment given on a couple of small points. He substituted "international atomic weights" throughout, in place of the ordinary round figure values, and made due allowance for the effect on the composition of the gases and the "oxygen equivalent" of the pig iron by the addition to the burden of 5.8 per cent scrap on the make of pig iron. The fundamental data obtained by Mr. Maccoun and given in the Year Book for 1915 of the American Iron and Steel Institute remained untouched.

The suggestion that the carbon burnt above tuyeres is a fixed quantity for a given burden may be challenged, on the ground that the use of soft coke increases the proportion of CO in the gases, and that this increase in CO is due to the reaction $CO_2 + C = 2CO$; which reaction would result in a consumption of carbon above tuyeres.

The author has not seen any comparative analyses based on the proportion of atmospheric $N_2$ to a unit carbon burnt at tuyeres which would prove this point, and in default of such analyses he suggests that the increase in CO is due primarily to physical causes. His reasons for so doing are twofold:

a. Owing to the great efflux of $CO_2$ from the decomposition of the limestone and the comparatively high temperature prevailing in this zone of the furnace, it is reasonable to suppose that the equilibrium $\frac{CO_2}{CO}$ corresponding to the conditions and temperature prevailing at this point will be satisfied, and that the reaction $CO_2 + C = 2CO$ will take place. Once this zone is passed, however, the proportion of $CO_2$ necessary to form an equilibrium increases with such rapidity as the temperature falls that, taking into consideration the velocity of the ascending gases, it appears probable that at no time after they have passed through this zone will the formation of $CO_2$ be sufficiently rapid to overtake the equilibrium demands. The tendency, in fact, would be towards the reaction $2CO = CO_2 + C$ rather than towards the converse.

b. Assuming that the reaction $CO_2 + C = 2CO$ actually does take place, once the gases have passed up through this zone of decomposition of the limestone there is always an abundant quantity of deposited carbon present in an exceedingly favorable condition for chemical reaction, and it appears probable that the $CO_2$ would take this carbon in preference to attacking the soft coke. As carbon deposited by the reaction $2CO = CO_2 + C$ is entirely carbon previously burnt and simply transferred, it would not show as an addition to solution loss.

The cause for this increase in CO, and consequent increase in the consumption of fuel when using soft coke, may be that, as the coke descends in the furnace, abrasion and crushing take place, causing "fines", and that these "fines" tend to fill up the interstices in the burden; the velocity of the gases is thereby increased, giving them less time to react with the ore, whereby less $CO_2$ is formed, the proportion of CO is increased, and the calorific efficiency of the carbon unit is decreased.

This view is supported by the fact that a considerable saving in fuel has been observed when the charge has been crushed to a uniform size. Apart from any economy which may occur from the practical consideration that uniform size of ore makes for uniform reduction and consequently uniform working, when the materials of the charge are all reduced to the same size, the maximum amount of free space between the individual particles is obtained. The velocity of the gases is thereby decreased, giving them more time to act on the ore, whereby more $CO_2$ is formed, the calorific efficiency of the carbon unit increased, and the amount of fuel necessary per ton of pig iron diminished in consequence. In both the above cases the amount of loss or gain in the heat, brought about by the change in the proportion of $CO_2$, would effect the intervention of the geometric ratio described previously, and the primary effect would be intensified in proportion.

If a furnace be blown with oxygen-enriched air, a diminution in the weight of gases per unit carbon burnt at tuyeres results from the reduction in the proportion of $N_2$ present in the blast. There will be consequently an increase in the amount of heat absorbed by the burden due to the decrease in the value for $w_2$ in the formula—

$$a_2 = \sqrt{\frac{c_2 w}{c w_2}}$$

The increment of heat to the furnace from this source will also be subject to the geometric ratio. Even taking this effect into consideration, it will be clear from the above that not much economy is to be awaited from a small increase in the percentage of oxygen in the blast, especially when it is recognized that there is at the same time a reduction in the amount of heat conveyed to the furnace per unit carbon burnt, due to the diminished proportion of $N_2$ in the mixture blown.

The conclusions to be arrived at from the premises in this paper are:

1. That a relationship exists in the blast furnace between heat added *to* and heat developed and absorbed *within* the furnace, whereby the ultimate calorific effect of a variation in the heat supplied is in geometric ratio to the amount of the initial change; and consequently,
2. That for countries with such a low average absolute moisture as England, it does not pay to install the dry-blast.
3. That the crushing of the materials of the charge to a uniform size may be expected to result in a considerable economy of the fuel required per ton of pig iron.
4. That the process of blowing with oxygen-enriched air is not likely to result in any appreciable saving for a small percentage increase in the oxygen.

In conclusion, the author wishes to express his indebtedness to Mr. Maccoun, whose admirable work was of the utmost assistance to him in the development of the views brought forward in this paper. To his brother, J. Spencer Hollings, likewise he offers grateful thanks for much kindly help in revising the text.

# Blast Furnace Built in South Wales

## New Plant of Messrs. Baldwins, Limited, at Margam Iron and Steel Works, Port Talbot, South Wales, Now in Operation. Description of Furnace and Gas Cleaning Plant.

THE contract for the blast furnace plant for Messrs. Baldwins, Limited, at the Margam Iron and Steel Works, Port Talbot, Glamorgan, was carried out to the design and specification of Mr. David E. Roberts, Consulting Engineer, Cardiff, who supervised and approved all the details embodied in the construction during the progress of the work.

The special type of furnace charging equipment provided, now covered by the Wrightson-Ringquist Patents, was brought about to meet the stringent conditions laid down by the consulting engineer in his specification, wherein he insisted that the charging of the furnace, when proceeding at the maximum speed, should be carried out without vibration to the structure or any swinging of the bucket.

The contract consisted of two blast furnaces, four dust catchers, two patent furnace chargers, 10 hot blast stoves, two steel chimneys, one 35-ton wagon hoist, one wagon gravity drop, 36 delievery spouts for material bunkers, three double scale cars, 30 coke cars, four electric transfer cars, 36 ore and coke buckets, one pig-bed gantry and crane, one dry gas cleaning plant, and gas, cold and hot blast tubing.

### Blast Furnaces.

The dimensions of the furnaces are: height from hearth to top platform, 84′ 0″; hearth, 12′ 6″ diameter; Bosh, 20′ 0″ diameter; throat, 15′ 0″ diameter; Bell, 10′ 0″ diameter.

The furnace castings are constructed of mild steel, resting on cast steel lintel girders which are supported on massive cast iron columns. The columns rest on cast iron base rings which are carefully bolted and dowelled together. All abutting surfaces are machined to answer accuracy and ease of erection.

Vertical joints in the casing havle double butt covers with four rows of rivets, and the circumferential seams are lap-jointed.

Hearth Jackets are of hematite cast iron and internally water-cooled and fitted with special segments at the tapping holes and slag notches.

The furnaces are provided with Main and Bosh Tuyeres, fitted in cast steel tuyere belts. The tuyere belts are machined and bolted together, and provided with openings to receive the copper coolers.

Cooling of the bosh is effected by flat copper coolers in addition to the tuyere coolers.

The circular hot blast Main is 4′ 0″ in diameter, and provided with branches for connecting up tuyeres.

Automatic drop valves are provided to circular main, and a hot blast valve is fitted to the branch leading to the circular main to enable the furnace to be isolated.

An auxiliary circular main is provided, placed about 12′ 0″ above the principal hot blast circular main, and fitted with branches for coupling up the bosh tuyeres.

Cold blast connections are provided to both circular mains.

Cooling water is supplied to the coolers by means of 10″ diameter cast iron mains with two 10″ branches, supported on cast iron saddles, secured to brackets on the columns. These mains are provided with branches for 4″ sluice valves connecting to the vertical manifold pipes.

All the cooling pipes are of brass and fitted with flexible or ball and socket joints where required.

Working platforms and bridges to the pig-beds are provided and arranged with suitable inclination at tapping holes and slag notches to obtain the flow of metal or slag, as the case may be. Access to the working platform from ground level is obtained by an iron stairway.

Mud guns and cranes are provided for each furnace.

The closing in of the furnace top is effected by a main bell and an upper auxiliary bell. The main bell has a three-point suspension on an annular ring, which is supported from the bell beams.

The suspension rods slide in floating stuffing boxes. By the three-point suspension of the bell, vertical movement is secured.

The bells are raised and lowered by means of hydraulic cylinders which operate at the outer end of the bell beams. The bell beams are rotatively supported on massive cast iron columns.

The auxiliary bell is kept closed by means of weighted levers terminating in jointed half spherical supports. These bells or seals are lowered by the weight of the charge in the buckets, and the vertical descent of the seal is ensured by a simple parallel motion arrangement of the two weighted levers previously mentioned.

Water pressure of 750 lbs. to the square inch is employed for operating the hydraulic bell cylinders. Two cylinders are employed at each furnace.

**Dustcatchers.**

Two dustcatchers are provided for each furnace, being respectively 24′ 0″ diameter by 40′ 0″ and 20′ 0″ diameter by 30′ 0″, connected to the furnace by means of the downcomers. Isolation valves are provided at the top of each dustcatcher, and also the usual dust outlets at the lower cones.

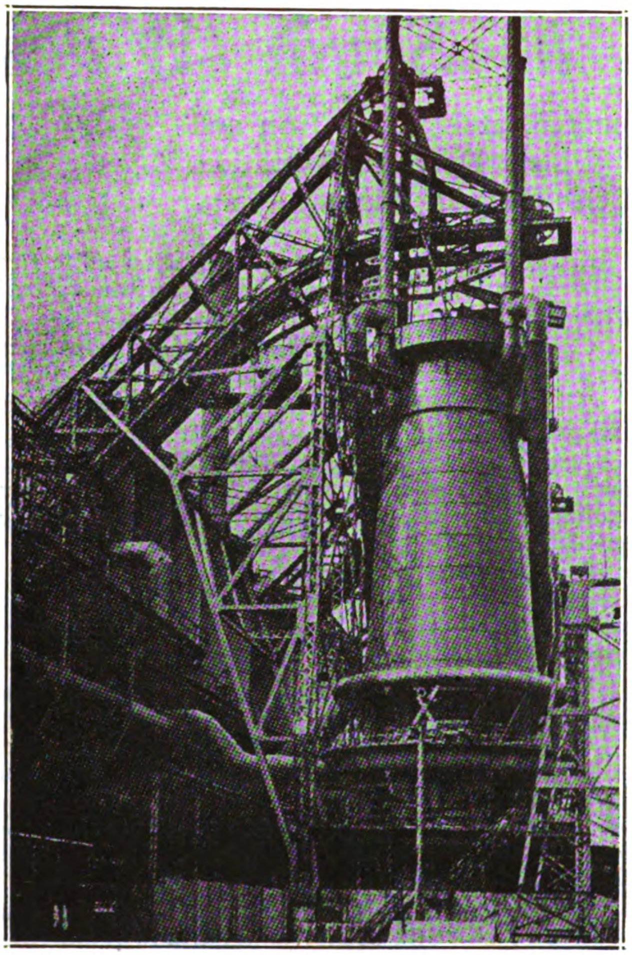

**Fig. 1—Side view of furnace showing charger with independent support.**

**Blast Furnace Chargers.**

Two incline chargers (Wrightson-Ringquist patent) are provided at present, but provision is made for installing another furnace and charger at a later date.

The chargers are designed for bucket charging, each bucket having a capacity of eight tons of ore and limestone or four tons of coke.

Each charger is capable of charging into each furnace 100 tons of raw material per hour, say, 70 tons of ore and limestone and 30 tons of coke, the maximum hoisting speed on the incline being 6′ per second.

The charger bridge is of latticed steel construction in one span from machinery trestle to the trestle at the furnace end of the bridge.

This latter trestle is carried down to ground level, and no portion of the charger is supported on the furnace casing.

The lower extension of the charger bridge to the bunkers and coke road is built as a cantilever from the machinery trestle.

The total length of track on the hoist bridge is about 200 feet, and the highest point on the charger at the furnace is 160 feet above ground level. The trestles and bridges are constructed of rolled steel joists and sections, strongly cross-braced and riveted together to withstand the stresses due to wind and hoisting the load at the maximum speed.

The machinery trestle is extended over the charger bridge to carry the machinery house and hoisting mechanism.

The charger bridge is provided with the necessary tracks for the traveling bogie inside the girders and for the traveling balance weight on top of girders. Provision is made at the upper and lower ends of the bridge as shown for the conveyance sheaves for hoisting, and balance weight ropes, and at intermediate points for the guide rollers and sheaves for supporting same.

Stairways and platforms giving access to all sheaves, machinery house, furnace tops and stove tops are provided, the main stairway being arranged on the top boom of the bridge outside the balance weight track.

A double line of wrought iron handrailing in massive cast iron standards is provided for all stairways and platforms.

The travelling carriage or bogie from which the bucket is suspended is of special design possessing several patented features designed to increase efficiency in working, together with ease and increased accuracy of location of the bucket both when depositing on the top of the furnace hopper and on the coke and scale cars.

The carriage consists of a mild steel framework carried on six cast steel trod wheels accurately turned on the tread. The front end of the carriage from which the bucket is suspended is carried on two equalizing bogies each mounted on two trod wheels. The tail end of the carriage is carried on two trod wheels running on the same track. The front end of the carriage is supported by means of a forged steel shaft passing through both side members of the carriage and having the bogie, free to swivel, mounted on either end.

The charging bucket is suspended from the traveling carriage by means of a heavy forged link chain passing over a sprocket wheel of special construction rotatively mounted in the center of the shaft secured to the forward end of the carriage. One end of this chain is provided with a special hook to engage the forged button on the top of the suspension rod or "stalk" of the bucket. The other end of the chain is attached to the rear end of a pair of toggle levers. These toggle levers are fully extended while traveling up the incline, but are arranged to "close up" when lowering the bucket on to the furnace top.

The rear end of the toggle levers to which the suspension chain for the bucket is attached is arranged to slide in the side members of the carriage when the same is in position over the furnace.

A cast steel trod wheel is rotatively mounted on the center hinge pin of the toggle levers, and arranged to run upon a single inverted rail secured to the hoist bridge, on the center line of the charger and above the bogie track. This inverted rail is curved upwards at the top end of the charger bridge to a radius equal to the length of the forward toggle lever to permit of the toggle levers "closing up" for the purpose of lowering the bucket on to the furnace top.

Sway of the bucket due to either wind or the rapid acceleration and retardation necessitated by the increased speed of working of the charger is prevented by means of a steadying arm running in a track on the bottom boom of the charger bridge and attached to the front end of the traveling carriage from which the bucket is suspended. The steadying arm causes the bucket to hang slightly out of the vertical when travelling up the charger bridge to an amount which insures that the pressure of the bucket against the steadying arm is always in excess of the wind, and acceleration and retardation forces acting on the bucket. Sway of the bucket is consequently prevented by the action of gravity alone without the introduction of any mechanism.

The balance weight running on the top of the charger bridge is attached direct, by means of twin flexible steel wire ropes reeved over the conveyance sheeves at the head of the charger to the front end of the carrying framework.

It is of suitable weight to equalize as far as possible the demands on the electrical equipment of the charger both when hoisting the full bucket and lowering the same empty.

The balance weight is of cast iron and made in sections being bored out to receive the forged steel axles of the cast steel trod wheels.

Twin hoisting ropes and tail ropes are fitted and either rope is designed to carry the full working load in the event of the other one breaking. Suitable whiffletrees are fitted to equalize the load on each of the twin rops.

The hoisting ropes are attached at one end to the hoisting drum in the machinery house, led therefrom over the conveyance sheaves at the head of the charger, reeved over the conveyance sheaves, mounted on the rear joint pin of the toggle levers on the carriage and anchored by means of a whiffletree to the forward end of the carriage or bogie framework.

The tail ropes are similarly attached at one end to the hoisting drum in the machinery house, led over floating conveyance sheaves at the tail end of the charger bridge, reeved over conveyance sheaves on the rear joint pin of the toggle levers, and anchored at the rear end of the carriage or bogie framework.

The conveyance sheaves at the tail end of the charger bridge are mounted on gudgeons with cast iron guide blocks arranged to slide in guides in the charger framework. A wrought iron stirrup connects the conveyance sheaves to floating balance weights working in vertical guides arranged inside the machinery trestle.

A constant and uniform tension is thus maintained throughout the whole rope system of the charger, which considerably facilitates the accurate location of the charger bucket both when hitching on at coke and scale cars and depositing same on the furnace top.

With the rope system as outlined above, the movements of the carriage and charger bucket are always under positive control, and at no time during the complete cycle of operations is it possible for the load to take control. Lowering of the bucket on to the furnace top is effected without reversing the direction of rotation of the hoisting mechanism. The tension induced in the rope system throughout the charger by means of the tensioning arrangement, as described above, is always in excess of the maximum "out of balance" rope pull at all positions of the charger carriage and bucket.

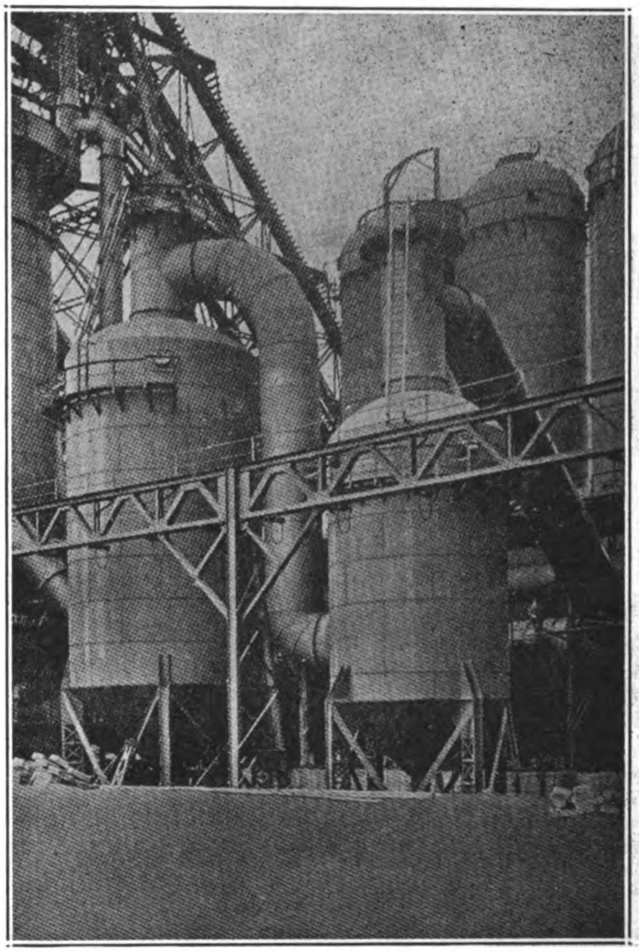
Fig. 2—Dust catcher, showing downcomers and branch to gas main.

The hoisting mechanism consists of a cast iron drum operated through two reductions of spur gearing by either of two motors with Ward Leonard control.

The cast iron hoisting drum is 6 feet 0 inches in diameter, and is accurately turned and grooved in the lathe to take the hoisting ropes and tail ropes and bored to take the forged steel drum shaft. Sufficient grooves are provided on the drum to take both sets of ropes without overlapping and having mild steel caps. The bearings are supported on cast iron stools with provision for horizontal adjustment, bolted direct to the mild steel girders of the machinery house floor. Cast steel single helical toothed rims are secured to either end of the hoisting drum and form together a double helical steel with the drum between the two halves. The two forged steel single helical pinions mating with the two spur rims on the drum are keyed to either end of the second motion shaft and secured against endwise movement.

The second motion shaft is of forged steel turned the full length and revolving in four cast iron pedestal bearings bushed with gun-metal and having wrought steel keeps. The pedestal bearings are secured direct to extensions of the hoisting motors bedplate. The cast steel first reduction spurwheel is keyed to the center of the second motion shaft.

The first motion shaft with the pinion forged solid with the shaft revolves in two independent pedestal bearings, duplication of those for the armature spindle of the hoisting motors.

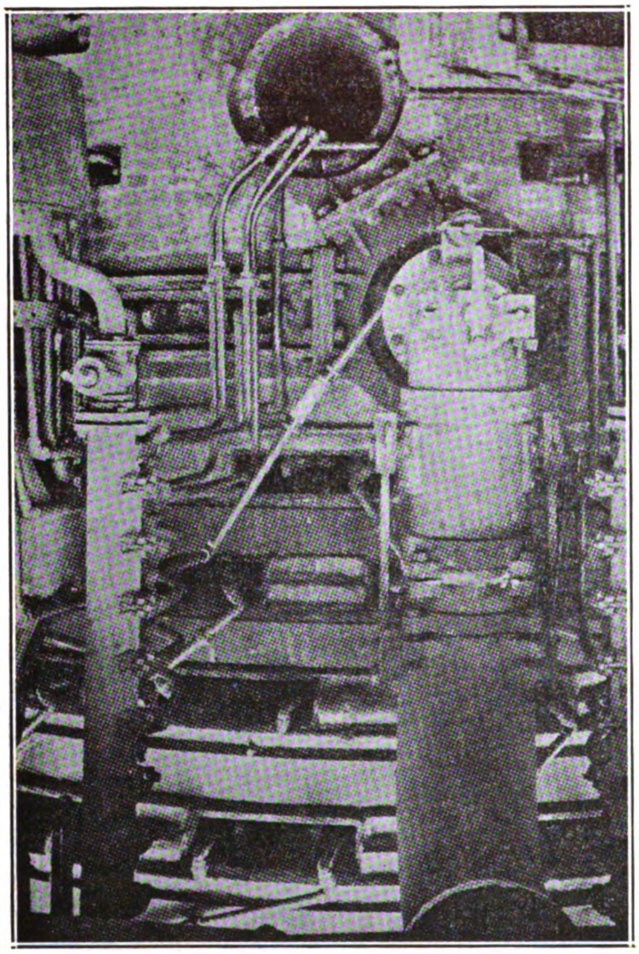

Fig. 3—Tuyeres, cooling system and slag notch.

The teeth of both sets of gear are of helical formation, and the first reduction gear revolves in a mild steel gear case and oil bath.

A cast iron brake drum is keyed to either end of the first reduction pinion shaft with one half of a claw clutch cast integral with each drum. One of the drums is for use in connection with an automatic solenoid brake, and the other as an emergency hand-operated brake. Both brakes are of the post brake type with cast steel shoes lined with "ferodo," and fitted with suitable linkages for coupling up to the magnetic solenoid in one case, and the brake lever mounted in the control cabin at ground level in the cast of the other.

Either brake is of ample power to deal with the maximum, "out of balance" pull of the ropes at any part of the cycle.

Two hoisting motors are provided for each charger, and either is capable of being coupled at will to the first motion pinion shaft by means of a sliding clam clutch. Only one motor is used during normal working of the charger, the other motor being held as a spare in case of breakdown. Stoppage due to motor trouble is thus reduced to a minimum; the work of declutching one motor and coupling the other occupying a few seconds only.

Each of the two hoisting motors is of the separately excited shunt wound protected type.

Each motor has the armature shaft extended at one end to take the sliding half of the claw clutch referred to above, for coupling either motor to the first motion pinion shaft as desired. Both motors are mounted on a special cast iron bedplate built in halves to facilitate assembly, and bolted direct to the mild steel girders under the machinery house floor.

The motors are controlled on the Ward Leonard system, a feature of which is that the speed for any given value of the generator field is practically constant, and at the same time independent of the load, whether that load is being hoisted by the motor, or itself driving the motor and regenerating into the line.

Three Ward Leonard motor generator sets are provided for the two chargers, each consisting of ac slip-ring induction motor, shunt wound separately excited generator and exciter complete, with necessary couplings and combination bedplate.

The motor generator sets and switchgear are installed in a separate house situated between the two chargers up against the ore bunkers.

The switchgear is such that one of the three generator sets can be connected to either of the hoist motors so as to act as a spare. Furthermore the switch is so arranged that either of the shunt wound hoisting motors in the machinery house can be connected to its corresponding Ward Leonard generator set, or the spare generator set as required. Double throw switches are provided whereby the above-mentioned switching operations can be affected.

Two Ward Leonard controllers, one acting as a spare, are coupled up in each of the machinery houses of the chargers and arranged to operate in conjunction with the accelerating gear.

The accelerating gear is so arranged that the control of the charger is taken out of the hands of the driver either at the coke or ore roads with the exception of stopping the charger, which can, of course, be affected from any point at will. The control gear is also so arranged that should the driver inadvertently miss the skip with the hook at starting, he will be able to return to pick this up again both at the ore and coke roads.

The switchgear for the two charges consists of three sections, as follows:

1. Installed in motor generator house.
2. Installed in No. 1 machinery house.
3. Installed in No. 2 machinery house.

The switchgear installed in the motor generator house consists of six panels, three high tension for the control of the three high tension motors, and three low tension panels for the control of the dc side of the Ward Leonard sets.

The high tension cubicles are of the sheet iron type in which the high tension apparatus is mounted in sheet iron compartments, the front of which consists of black enamelled slate on which is mounted the instruments and the operating handle of the oil switch. A door is provided at the back fitted with a lock so as to give access to the interior.

The oil switches are of the triple pole, automatic, loose-handle type, provided with a common tank for the three phases, and fitted with two over-load trip coils and one no-volt coil, the two overload trips being connected to a polyphase overload inverse time limit relay, which is connected to two air-cooled transformers, giving complete protection on a three-phase unearthed system.

The switchgears in Nos. 1 and 2 machinery houses are exactly similar, each consisting of one panel per charger, equipped with 1-6 P., D. T., Q. B. knife switch, 200 amperes, fitted with special discharge contacts and two discharge resistances, with auxiliary switches.

Each charger is controlled from a cabin at ground level at the foot of the machinery trestle of the charger, so that the driver has an interrupted view of the hook of the charger when hitching on the bucket at both the coke and ore roads.

Each control cabin is equipped with a mild steel framework on which is mounted the levers by which the charger is controlled, viz., reversible field controllers; accelerator gear selector clutch for ore and coke roads; mechanical emergency brake control; solenoid brake release.

There also is fitted the carriage or bogey indicator and limit switch and two stock indicators, each with a range of 16 feet inside the furnace.

The motion from the various levers and indicators is transmitted to the corresponding mechanism in the machinery house by means of steel wire ropes, suitably tensioned by floating weights, and fitted at either end with bush roller chains and sprockets, so that the movement of the various controls in the machinery house is accurately indicated and reproduced by the movements of the levers in the control cabin.

**Hot Blast Stoves.**

Ten hot blast stoves of Cowper type, 90 feet 0 inches high to the springing of the dome, and 21 feet 0 inches diameter, are provided for the two furnaces.

The stove casings are of mild steel and fitted with firebrick chequers, having 4¾ inch ducts and 1¾ inch walls with an effective heating surface of 77,000 square feet per stove, and a volume of 2,500 cubic feet.

The volume of brick lining, together with the wall in the combustion chamber equals 11,000 cubic feet.

The gas valve is of the slide cut-off type, mounted on a rectangular gas box of cast iron. The down pipe from the clean gas main is also mounted on this box. When the gas valve is racked out, away from the stove, a heavy cast iron door of dish form, provided with rollers running on a rail attached to the brackets cast on the inlet mounting, is placed in position and firmly clamped over the face of the inlet with heavy cast steel yoke, substantial swinging bolt and deep wing nut. Both inlet casting and door have their faces machined. When the stove is on blast there is, therefore, no leakage of hot blast, and the gas connection is isolated from the stove.

The two air valves of disc type are 18 inches in diameter, made of cast steel bodies, bolted on cast steel branches attached to the stove shell. They are arranged to open inward, and when they are closed up on the machined faces, the air pressure inside the stove presses the valves more firmly on their seats. They are of substantial design, and are operated by hand wheel and bevel gearing. The hand wheels are fixed at a suitable height from the ground level for operation. A sight hole with cover is provided in each valve so that the gas flame may be inspected from time to time.

The chimney valve is of the slide cut-off type, having a clear opening of 3 feet 6 inches diameter. The bend, which is of mild steel, is mounted on a cast iron base and fitted with a steel damper plate to shut off the flue gases when the stove is on blast. The base plate, slide and slide frame are mounted directly on top of the chimney flue. The cut off is a heavy iron casting of "spectacle" ferm, balanced on a steel center pin. One half of this "spectacle" is a blank to close the opening when stove is on blast, the other half being an angular ring or eye of the same thickness as the blank to fill the space between the branch and bend when the stove is on gas. The branch mounting on the stove projects four feet from the shell, and is provided with a heavy cast iron machined flange, with four lugs for swing bolts, and a large boss for the center pin, on which the spectacle is turned. The chimney valve bend is provided with a similar flange. The swing bolts are of ample proportions with square cut threads, each nut having a lever pinned on it. By slacking back the four nuts, the swing bolts are turned clear of the "spectacle", which is then turned into the position for gas to pass through the eye, or the blank portion is interposed, the swing bolts are returned to their lugs, and the nuts screwed up. This type of valve ensures a perfectly tight joint against the blast in the stove, and there is no loss of pressure when on blast, nor any leakage from the chimney flue into the stove should the stove not be in use for any length of time.

The cold blast valve is bolted to a short length of tubing riveted to the top of the chimney valve mounting. It is of the slide type, 24 inches in diameter and is operated by chain wheel, rack and pinion. To minimize the initial effort of opening so large a valve against the blast pressure, a small pilot grid is fitted to the back of the main slide. The first portion of the movement of the gear when opening the valve is used solely in opening the small pilot slide when, the pressure being relieved, the main slide is racked open with greater ease.

Each stove is equipped with a 12 inch relief valve ("disc type) fixed on the side of the chimney valve mounting, and is coupled up by bend pipe to the chimney flue.

The hot blast valve is of the balanced slide type, and is 26 inches in diameter inside the brickwork lining. The main body is of cast steel with a cast iron top or hood. The hood is provided with gland and stuffing box for packing the valve stem.

The valve seat is a thick cast iron water cooled ring. It is machined on both faces, one on which the valve seats, the other to fit an internal faced

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flange in the valve body and bolted thereto. The valve paddle is of cast iron 4 inches thick in the center and 4½ inches at the facing. It is not water cooled. The valve stem or spindle has a tee head, which fits into a slotted recess in the paddle. The other end of the spindle is formed into a socket into which a cast steel rack is cottered.

Double chains are attached to this socket and pass over pulleys mounted on the brackets above the valve casing. To the ends of the chain the requisite amount of balance weight is attached. The valve is operated by an endless chain working over a large pulley keyed on the outer end of the pinion shaft and brought to a convenient position at the base of the stove. Provision has been made in the design of the hot blast valve for the expeditious removal of the paddle and seat ring whenever a renewal is necessary. A large opening with a bolted flanged cover is provided at the bottom of the valve casing through which the whole valve paddle, stem, and rack may be lowered to the ground after taking out the cottered pin connecting the balance weight to the stem.

### Steel Chimneys.

Two mild steel chimneys are provided for the stoves, each 190 feet 0 inches high and 8 feet 0 inches diameter at top. The lower end of the chimneys are bell-bottomed, making them self-supporting, without excessive thickness of plates.

### Wagon Hoist.

One electric wagon hoist is erected at the south end of the material bunkers capable of raising a gross load of 35 tons from ground level to the top of the bunker in 30 seconds.

The framing of the hoist is constructed of mild steel plates and sections, strongly braced to withstand all combinations of stresses.

The cage or table is supported on four two part ropes reeved on the sheaves at each corner of the cage and thence over conveyance sheaves at the top of the hoist to the lifting drum. Compensating sheaves are provided in connection with the rear lifting ropes to equalize the load on all the hoisting ropes. Adjustment is provided at the fixed end of the lifting ropes to facilitate the trimming of the cage for the necessary inclination. The hoist mechanism is placed on the top of the hoist framing, and consists of two cast iron drums driven through spur reductions by an electirc motor. The control gear is of the contractor type. Automatic safety gates are provided at the top and bottom of the hoist.

### 35-Ton Wagon Drop.

One 35-ton gravity wagon drop is erected at the north end of the bunkers for lowering empty wagons from the top of the bunker to ground level, after they have been emptied into the bunkers. The drop is also capable of lowering a fully loaded wagon of gross weight of 35 tons if required. To obtain the requisite braking power it was found essential to fix the brake sheaves on a countershaft, otherwise the brake sheaves would have been an enormous size. The brake levers are so arranged that effort must be applied to release the brakes, thus ensuring the automatic action of the brakes, and the suspension of the cage at any point.

### Delievery Spouts for Bunkers.

The ferr-concrete bunkers are provided with 36 delievery spouts.

The sides and bottom of the spouts are made of mild steel plates and angles and are provided at the delivery end with cast steel quadrants. Each spout has three independent quadrants, so that the flow of the metal may be regulated, as by this arrangement one may open one-third, two-thirds, or the full width of the spout at any time, and thus ensure free flow of the metal. Spouts are operated from the scale car by means of hand-chains.

### Scale Cars.

The scale cars are fitted with the revolving turntables provided with seatings suitable for the reception of the material buckets. These tables are rotated by independent motors, and are attached to automatic weighing machines. The recording weighing mechanism for each machine is fitted with six steelyards enclosed in a lock-up case, each steelyard being lettered to correspond with the material to be weighed. An additional steelyard is fitted for registering the tare of the bucket, table, etc. The scale cars are propelled in front of the bunkers by means of electric motors and gearing, and all controls are located in the central cabin. Hand operated brakes are provided on each car.

### Coke Cars.

Thirty coke cars are provided to carry the coke buckets from the coke ovens, constructed of steel channels, plates, etc., and fitted with strong buffers, coupling hooks and chains at each end. The underframes are mounted on chilled iron wheels, fitted to mild steel axles running in oil lubricated boxes.

A hydraulic creeper is employed in the exact location of the coke cars underneath the chargers, so that the stalk of the bucket is exactly in line with the hook of the charger bogie.

### Transfer Cars.

The transfer cars are electrically operated, and are used for distributing ore, etc., throughout the full length of the material bunkers. The cars are of the hopper type, having two bottom doors so that the load may be quickly discharged. Each car is driven by means of the railway type motors, the controls being in the cabin at the end of the car. Door gear, brake and sand boxes are also operated from this cabin. The cars are also so designed that they can be employed as electric locomotives, capable of hauling four loaded standard wagons on the adjoining lines by means of chains attached to the sides of the cars.

The electric current is collected from live rails on one side of the track.

### Ore and Coke Buckets.

The buckets are designed to carry eight tons of ore or four tons of coke. They consist of cylindrical casing, terminating with a frustrum at the lower end. The bottom of the bucket is closed by means of a cone or bell which is firmly attached to the central stalk, which latter is free to move up or down in suitable guides. A cast steel seating is provided at the lower end of the bucket, on which the bucket rests when delivering its charge into the furnace, thus enabling the stalk to be lowered a distance of about two feet nine inches, giving a free opening between the bucket and the cone for the delivery of the material.

**Pig Bed Gantry.**

The pig bed is provided with a gantry of 85 feet span designed to carry two 10-ton overhead traveling cranes for handling the pig iron. The length of the gantry is 465 feet, this length being sufficient to command the output of No. 3 furnace whenever it may be built. The stanchions and girders are of mild steel sectional material, exceptionally well stiffened and braced. A platform has been provided alongside the crane girders and along the end girders, thus making a continuous walking way right round the gantry. A stairway at each end gives easy access from the general ground level.

**Gas Cleaning Plant.**

The gas is cleaned on the Halber-Beth system (supplied by the Fraser & Chalmers Engineering Works). The quantity of gas the plant is designed to clean is 4¾ million cubic feet per hour at 0°C and 760 m/m Hg. This will be cleaned down to a dust content of less than .005 grammes per cubic meter, with a total power consumption of less than 420 hp at a delivery pressure for the clean gas of three inches W. G. for stoves and boilers.

The economizer units for pre-cooling the gas are carried on girders in the cooling house at a height above the rail level of the works, to permit of the convenient removal of the dust collected in hoppers under the economizers.

The inlets and outlets on each unit of coolers are provided with water sealed valves, and on the clean gas side of the fans valves of similar type have been provided. Arrangements have been made to by-pass crude gas into the clean gas main for use at the stoves if required at any time. Water sealed valves are provided at this connection also. These valves have no mechanical parts, and are closed by admitting water to flood the chamber, and opened by discharging the water.

By means of these valves any part of the whole plant which may be under repair or undergoing renewal, is perfectly isolated and safe from the leakage of any clean gas.

**Gas, Cold and Hot Blast Tubing.**

The raw gas main, hot blast main and clean gas main are arranged one above the other and carried on same supports alongside of the stoves. The raw gas main, which is 9 feet 6 inches in diameter lined with 4½ inches of firebrick, has numerous dust hoppers on its lower side, and through a bell at the bottom of each of them the dust deposited by the gas is removed without interfering in any way with the operation of the plant. As a consequence of the frequency of the dust outlets, the full area of the main is available at all times for the unrestricted flow of gas. The downcomers from the dustcatcher of both No. 1 and No. 2 furnace are connected to this main, and a third furnace may at some future date be also connected to an extension of the main.

There is a continuous platform along each of the gas mains giving easy access to the explosion doors, and from the stove base level several are fixed to connect to these platforms.

The explosion doors have machined faces, and are constructed so that the doors may be bolted when the mains are in full working order.

There is one cold blast main 30 inches in diameter for blowing each furnace. As at present installed there are two such mains, but provision has been made with valves and by-passes so that a third may be added at any time, and connected up in any of the combinations as described above. At the outside of the power house the mains are so coupled together and valves inserted that any one or number of blowers may be connected to any main. All the valves on the cold blast mains are of the parallel slide type with double seats and faces, with a wedging action to press the valve faces firmly to their seats.

# Modern Process of Drawing Wire

## Practical Application Surrounded by a Great Many Technical Considerations With Reference to Speed of the Wire Through the Dies—Annealing and Composition of the Material.

By L. DWIGHT GRANGER,
Wickwire Spencer Steel Corporation.

AFTER the rods have been rolled, they are taken, bundle by bundle, by a conveyor and carried to the rod storage yard. Here they are accumulated in accordance with their chemical composition and heat numbers, and held until they are either shipped to a customer, or called for in the mill.

Wire drawing, in principle, is a very simple matter. It merely consists in pulling a wire through a tapering hole in some material that is harder than the wire, thereby producing an elongation of the wire and a corresponding decrease in diameter. The wire is then wound up on a block and the process of elongation and reduction repeated as many times as are necessary to produce the finished size of wire desired.

The practical application, however, is surrounded by a great many technical considerations in which lie the art and skill of the experienced wire drawer and wire mill foreman. In order to run properly, the rods must be properly prepared; the wire drawing die must have a hole of proper taper and length; the amount of reduction must be suited to the particular kind of metal that is being treated; the speed, also, at which the wire passes through the die must be carefully adjusted to the size and kind of wire. Taking all of these considerations together, it can readily be seen wherein the troubles of a wire mill man can be multiplied by carelessness, inattention, or lack of knowledge of any of these details, small as each may be in itself.

When rods are received from the rod mill, they are covered with a scale consisting of iron oxide in one

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From the Triangle Clan.

or more of its forms. This iron oxide is a very hard and brittle material, and, if not removed from the surface of the wire, would cut out the hole of the die very quickly. The first operation, then, is to remove this surface scale. This is done by standing the bundles of rods on end, putting a yoke over them and a pin through the eye, so that the coils will hang fairly loose on the pin. The pin of rods is then put into a bath of heated sulphuric acid of low percentage (not over 5 per cent). After an immersion of from five to 15 minutes, in accordance with the practice followed at various mills, the scale has been removed, and the silvery gray color of the steel appears on the surface. Any loosely adhering dirt or scale is washed off by means of a stream of water played on the pin of rods, at a pressure of 150 pounds per square inch or more.

For some purposes, after this treatment, the pin of rods is placed under a shower bath and allowed to take on a wet rust coat, after which the rods are dipped into a bath of lime and placed in the dry house. If the rust coat is not desired, the rods are put into the lime bath immediately after the washing.

During the time that the rods have been immersed in sulphuric acid, they have exerted a very peculiar tendency to absorb hydrogen gas in enormous quantities from the sulphuric acid. This makes the wire "acid brittle" and in order to overcome this condition, it is necessary to expel the gas by means of heat. For this reason, the rods are put into a dry house, which is heated to about 350 degrees F. and allowed to stay there from four to eight hours, according to the kind of material, at the end of which time the gas has been driven off and the lime dried, so that the rods are in condition for drawing.

Up to this point, the treatment of high carbon and low carbon rods is practically the same, slight differences, such as temperature and strength of the acid, and length of time of baking, being the main points to be considered. We will first take up the drawing of soft, or low carbon stocks, such as are used for netting wire and weaving wire.

### Drawing Soft Stocks.

Soft, or low carbon stocks can be drawn further than hard, or high carbon stocks. In order to illustrate the various processes, we will consider the practice for drawing the wire that is used for weaving fly screens. A No. 5 rod is cleaned, rusted, and lime coated, baked until the acid is removed, and then is carried to the rod frame. This rod frame consists, usually, of five blocks, the first two run at a lower speed than the last three. The wire is drawn by means of four successive drafts, to No. 14 gauge. This point has been found, by experience, to be the most economical one at which to anneal for further drafting, although a five rod can be drawn as far as 17 or 18 gauge, without annealing, when a hard drawn wire is desired.

After a wire has been drawn a certain number of drafts through different dies, it becomes so hard and brittle that further drafting would cause breakage and an actual disrupting of the structure of the steel. Before this point is reached, it is necessary to relieve these strains and put the wire into condition for further working, by means of a heat treatment, called annealing.

Annealing may be done either in a muffle or a pot. The muffle furnace has an open chamber, heated by means of the gases from a fire box in which a long flame coal is burned. The wire is then thrown on the hearth of the muffle, the door is closed, and the fire started up. A great deal of the success of this operation depends upon the furnaceman, and it is desirable to maintain at all times a slightly smoky flame, so that the surface of the wire shall not be too much oxidized or scaled. After the wire has attained the proper temperature, the coils are hooked out onto the cooling floor, and a new batch of wire thrown in.

This process has been almost entirely superceded in the wire mills of this country by the pot annealing process. A pot is a cylindrical casting of iron or steel varying in diameter from nine inches to 40 inches, made in accordance with the kind of wire to be annealed. Its height is usually in the neighborhood of seven feet.

Wire to be annealed is brought in by the wheelers and thrown coil upon coil into the pot, until the pot is full. At times, we may nest a 16-inch coil inside of a 22-inch coil and an eight-inch coil inside of the 16-inch, so that the space in the eye of the coil is utilized. After the pot is full, a cover is put on and the joints between the cover and the pot sealed with fire clay. According to the best practice, the pot is loaded outside the furnace and is lifted by a crane and put into the heated furnace, from which another pot has just been taken. In this manner it is possible to anneal three pots of wire during the 24-hour day, in each furnace. Some mills have pots which are not removable from the furnace and in these only one pot a day can be annealed.

When the pot is in place in the furnace the temperature is slowly raised to the degree desired for annealing. For ordinary process annealing, on wire which is to be drawn further, a lower temperature is necessary than for wire which is desired dead soft. Just before the desired temperature is reached, the dampers of the furnace are closed and the heat is allowed to soak through the pot, so that the entire contents are brought to an even degree of heat.

At the end of the operation the crane hooks onto the pot, lifts it out and deposits it in a cooling pit where it stays until the wire is cool enough to remove without causing a scaling action.

After this annealing, the wire is again cleaned and coated, as in the case of the rods, and is drawn by a further number of drafts to 19½ gauge. This drafting is done, either on a "15 frame" or on a continuous machine. A 15 frame may consist of from eight to 12 blocks sixteen inches in diameter and running at a standard speed.

At 19½ size the wire is again annealed and sent to the wet wire department for further reduction. In all of the dry drawing, powdered soap is used in the die box as a lubricant. This in combination with the lime on the wire forms a slippery substance which exists as a film between the surface of the wire and the die.

The success of wire drawing so far depends upon the proper preparation of the rod, the proper length of bearing and taper of the die and the proper use of soap. All of these things constitute the art of wire drawing and contrary to the impression, which has been carefully fostered by some of the old school, there is no mystery to any one of these operations. They are all reducible to absolutely definite conditions and in case trouble is encountered, in the words of the cereal manufacturer, "there's a reason."

At 19½ the wire is cleaned in "hand boxes." The annealed wire is thoroughly opened out so as to enable the acid to reach every part of the coil. It is then cleaned, usually in a mixture of sulphuric and muriatic acids, thrashed either by pounding it with a big stick or on a machine made especially for the purpose, given another light dip in sulphuric acid and then put into barrels and covered with a weak mixture of rye meal and water.

After standing in this mixture for a few hours, it is ready for drawing wet to the finished size. This is usually done in two operations; it is first sent to a drawing-out frame where the wire drawer dips the wire into a coating solution made by dissolving feathered tin in a solution of blue stone or copper sulphate. When the wire has taken on a sufficient amount of coating, it is put on the reel in a tube containing a stronger solution of rye meal and is drawn out from the 16-inch coil into an eight-inch coil, usually two drafts to 21½. The drafting through the die burnishes the copper and produces the well-known bronze color which is characteristic of liquor finished wire. The drawn out wire is then put into a box and distributed among the finishing frames where it is drawn by a further number of drafts to 33 and 34 without further coating. The wire is kept immersed in the rye meal liquor all the time it is being drawn and by the time the finished size is reached, if no difficulties are encountered, the coating is distributed so finely on the surface that scarcely a trace of the original copper can be seen. This is the weaving wire which is used so largely in our mills for the manufacture of fly screen cloth.

So far we have considered only the drawing of soft stocks which, as we have seen, are annealed at various points when the amount of drafting is such that an attempt to draw further would result in an increased amount of breakage and therefore shorts or scrap. In the case of high carbon stocks the procedure is considerably different.

### Drawing Hard Stock.

The best wire drawing practice for high carbon stocks calls for an initial heat treatment of the rod. termed patenting. This consists merely of running rods continuously through a furnace heated to a considerable degree above the critical point and cooling rather quickly in the open air. A certain structure is produced in the steel which can be readily identified under the microscope and which imparts a greater toughness and ductility to the steel than annealing.

The various structures which steel takes on, will be described and illustrated in a future article in this series. After patenting the rods are cleaned, rusted and lime coated the same as before, and are drawn to certain standard points in accordance with the size of wire to be finished. High carbon stock of course, must be drawn with lighter drafts than low carbon stock on account of the greater stiffness of the material itself. A .55 carbon stock may be drawn considerably further than an .80 or .90 carbon and a great deal of the success of the layout of the process depends upon the knowledge of the man in charge as to how far wire may be drawn and by what drafts.

The production of rope wire generally calls for at least two patentings; one in the rod and one or more at some intermediate size, depending upon the size of wire to be finished.

In the case of the higher carbons and finer sizes, the patenting operation is further developed by bringing the wire from the heating furnace into a quenching bath of lead which is maintained at the proper temperature to give the physical properties desired at the patenting point. This not only produces a more uniform wire, but also cuts down the loss occasioned by the fairly heavy scale that is produced by bringing the wire directly out into the air.

### Net Wire Heating.

For the production of coppered and liquor finished wires, we have a somewhat different method of procedure. Most of the orders call for sizes which are drawn dry to within one size of the finished size of wire. This dry drawn wire is then cleaned on the wet wire crane and wheeled to the wet frames where it is kept in tubs containing a weak solution of rye meal liquor until the wire drawer is ready to handle it. He then coats it in the bluestone and tin mixture very much the same as the weaving wire is treated, washes it, dips again in a soap solution and then puts it on the reel in a tub of liquor from which it is drawn through a steel or cast iron die to the finished size. The finer sizes are sometimes drawn two or more drafts to finish, but the coarser sizes are usually one draft work.

### Continuous Wire Drawing.

The process of drawing wire continuously, that is, several drafts in succession without taking off the block and putting on the reel again, as is done with single drafts, is in the process of experiment and evolution. Various machines are on the market both for dry and wet continuous drawing and it would seem that a large part of the progress of the art of wire drawing lies in the development of a successful machine for continuous drafting. This is successful on the finer sizes of wire and must be worked out to a successful conclusion on the coarser gauges.

We have seen in this brief account of wire drawing that the principle is one of the simplest things that can be considered, but that its application is surrounded by a great many difficulties which have required the study of a great many men to perfect. We may say that wire is made in the cleaning house. If the start of the process is not right, if the rods are not clean when they leave the acid vat, if the coating does not stick properly and if the acid is not thoroughly baked out, the best wire drawer in the country cannot make good wire. On the other hand, if all these things are done properly, it is hard for the wire drawer to spoil the wire. A great deal of responsibility lies also in the hands of the die box, as a very small change in the taper of the hole, length of bearing or shape of the reamer can cause endless trouble to the wire drawer and make a great deal of unnecessary scrap and rejections.

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## PRAISED REPRESENTATION PLAN.

Following an inspection of the Steelton, Pa., plant of the Bethlehem Steel Company, President Eugene G. Grace and other Bethlehem officials attended a banquet in the evening to mark the installation of new employes' representative. President Grace and other officials praised the employes' representative system in bringing about coöperation between the employes and the management.

# Selection of Alternating Current Motors for Mill Work

### As Use of Alternating Current Becomes Common in Industrial Plants It Becomes Important That Types of Motors Available for Use Be Studied Carefully.

By JOHN CONZELMAN.

As the use of alternating current becomes more and more common in industrial plants, it becomes important that the types of motors available for use with this supply of power be studied carefully.

Most all operating and mechanical men are familiar with the various types of direct current machines and their relative uses are well known and correctly applied. The alternating current motor is not given such fair treatment and frequently is called upon to do work for which it is not fitted or for which there is another type of motor much better fitted. It is the purpose of that which follows to bring out characteristics of various types of alternating current motors and to show why various types are peculiarly fitted for various uses.

In general, alternating current motors are classified as induction, repulsion—induction or synchronous. The induction type is again split up into classes according to its rotor winding as squirrel-cage or wound-rotor. Both types can be considered as either constant speed or adjustable speed according to the amount of resistance added or subtracted, i.e., cut out of the rotor circuit.

In direct current practice we are accustomed to use a series wound motor for loads that require frequent starting and stopping, that can be direct connected and where speed regulation need not be close. And again we find use for the shunt wound motor where a constant speed is desired and where the starting torque does not exceed full load torque by too large a margin. The compound motor combining characteristics of each of these types, sometimes leaning towards one, sometimes towards the other, depending on design, is adapted to loads of intermediate characteristics.

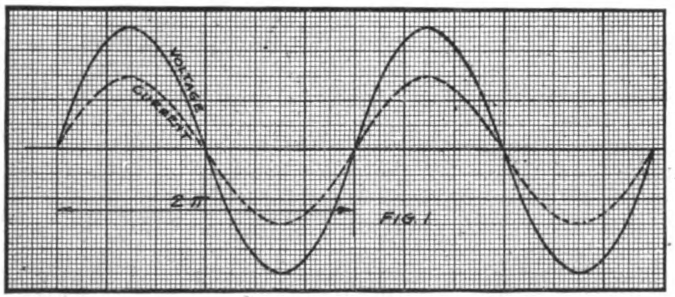


Fig. 1.

In the alternating current field there is no motor known today that can do the work required of the direct current machine-tool motor. This service demands an adjustable speed motor with wide range of speed adjustment and at the same time requires practically no change in speed from no load to full load on any setting.

Placing a definite resistance in the rotor circuit will reduce the speed of an induction motor to a definite value for a given load but the resistance at the same time introduces other characteristics. The drop in speed of an induction motor from no load to full load is called the slip and is proportional to the resistance in the rotor winding, i.e., high resistance means a high percentage of slip. It will be seen that a high resistance rotor in an induction motor will mean a large change in speed from no load to full load. This high resistance type of alternating current motor has characteristics comparing with the direct current series wound motor or the heavily compounded dc motor.

A low resistance motor on the other hand gives a motor characteristics comparable with a dc shunt motor.

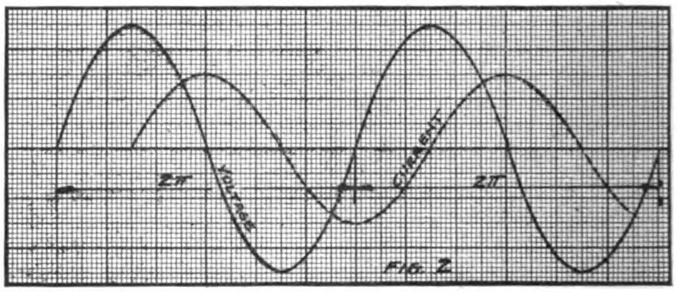


Fig. 2.

Low slip motors (two to five per cent) of either the squirrel-cage or wound rotor types are used on motor-generator sets, centrifugal pumps, textile machinery and other places where a constant speed is demanded.

An item of importance to the small generating station is the size of the largest motor of this type allowable on the line. The low slip squirrel-cage type motors produce most extreme conditions when starting and good practice demands that no motor of this type be connected whose capacity exceeds 30 to 35 per cent of the station generating capacity. The reasons are that this type takes a high starting current at a low power factor with a corresponding tendency to reduce the line voltage. This in turn further decreases the starting torque and frequently will mean stalling the motor and large overloads for the transmission line and generating station. The low slip type takes from 3½ to 4½ times full load current when starting.

The squirrel-cage motor with medium percentage of slip (say 7 to 12 per cent) finds use where the starting torque is high relatively to full load running torque. This type of motor when starting does not make such heavy current demands as the 2 to 5 per cent slip type and the running characteristics are admirably adapted to intermittent peak loads as are found in driving punching and stamping machines, shears, or machinery where a fly wheel is used. In this connection a 10 per cent variation in speed is advisable in order that the flywheel may deliver its stored energy. Frequently it is found that a motor has been installed of sufficient size to actually perform the duty cycle without the flywheel. This means that during that part of the cycle where little or no work is being done the motor is operating practically idle. This not only means that a large investment is tied up needlessly but it also means bad electrical conditions in the power circuit due to a low power factor. It is well to bear in mind that induction motors always tend to lower the power factor and that an underloaded motor produces worse conditions than one loaded up.

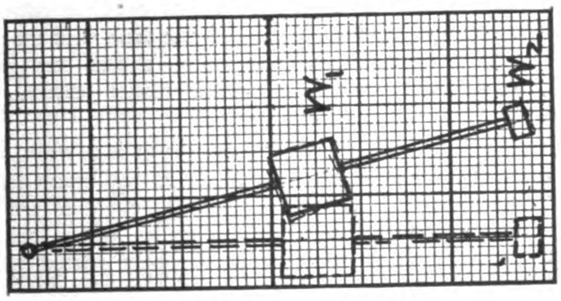


**Fig.** 3.

For traction work or hoisting the 15 to 20 per cent slip motor is used to advantage. This work demands a heavy starting torque. The running speed will depend on the load moved. This makes the ideal combination for this kind of work as the power will not vary much even with very excessive loads, the motor merely slowing up.

The question as to the most economical slip value to choose is a complicated one depending as it does upon the cycle to be carried, on the weight of the flywheel, the running losses, and so on. In a plant where operation is light for a considerable part of the cycle on various machines it would generally be advisable to select a motor with a fairly large slip and use a light flywheel so that the constant loss would be small. Again where the load is fairly constant, the interval between peaks being small, the slip and size of flywheel will bear an entirely different relation to the input and rated capacity of the driving motor. Under these conditions a heavy flywheel and a relatively small slip might be a most economical arrangement. Practice ordinarily calls for a slip of from 12 to 15 per cent. The energy stored in the flywheel is proportional to the square of the velocity and so by increasing the slip a proportional increase in energy stored is not obtained. A 15 per cent slip means that practically 28 per cent of the total energy may be stored in the flywheel, while for a 20 per cent slip the stored energy is only 36 per cent.

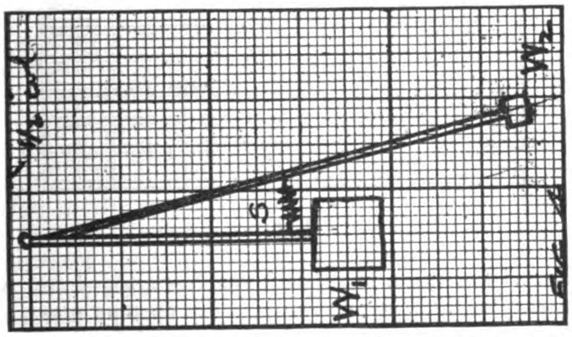
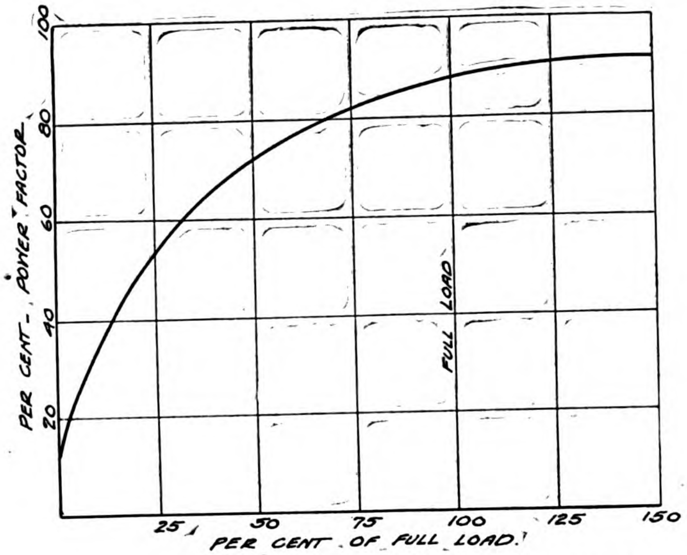


**Fig.** 4.

The repulsion-induction motor is used successfully where single phase current only is available. It has a high starting torque, two to three times full load torque for a reasonably low starting current. The pull-in torque is from one to one and one-half times full load and the breakdown or maximum load is about twice full load torque. Due to the fact that the rotor winding is short circuited under operating conditions this type of motor has a low slip characteristic and therefor good speed regulation. They are used with excellent results on rotary blowers, compressors, pumps, etc. They are automatic self-starting and require no starting device except a double throw switch or circuit breaker. Where especially low starting current is desirable a starting rheostat may be used although this reduces the starting torque proportionally.

The induction motor has been used and probably will continue to be used as the general purpose motor; the large proportion of all alternating current motors being of this type. The synchronous motor has always been admittedly superior to the induction motor in certain respects. A study of motors will reveal that the synchronous motor drops off very little in efficiency at part loads. They can be made for very low speeds and still develop extraordinarily high efficiency. They are essentially a constant speed motor and variation in line voltage does not effect their speed at all. They can be operated at unity power factor regardless of the power factor of the line and are used many times to correct a badly lagging current upon the line. A certain amount of power factor correction can be obtained without interfering with the motor's capacity for carrying its mechanical load. In fact a synchronous motor generally gives a higher percentage of power factor correction when carrying a mechanical load than it would if running idle or as it is called foating on the line as a synchronous condenser for the sole purpose of power factor correction. As far as uses are concerned the synchronous motor is limited by the following:



THE POWER FACTOR OF AN INDUCTION MOTOR.

**Fig.** 4-A.

It is absolutely a constant speed motor.

Its starting torque will vary between 20 and 40 per cent of full load torque.

For slow speed work they are particularly adapted for direct connection to air compressors, ammonia compressors, high pressure pumps, rubber mills, fan drives, etc., and for other constant intermediate speed work. Low speed machines are designed for speeds as low as 72 revolutions per minute. The compressed air and refrigeration field is particularly adapted to synchronous motor work and it is now unnecessary for the buyer to specify starting or operating characteristics as coöperation between motor and compressor builders have made it possible to get just exactly the right motor for each and any type of compressor. Up to the present line shafting has been almost exclusively driven by the induction type of motor. Particularly in mills using heavy machinery it is found that the line shaft friction will average between 25 and 40 per cent of the total load and so a motor with a good starting torque has been essential. Slip-ring induction motors have been generally used on account of their high starting torque and reasonably low starting current, but as the load on these mill lines is quite variable a low power factor often results. There are now installations where the power engineer has seen fit to install synchronous motors for this service and to install clutches to facilitate starting.

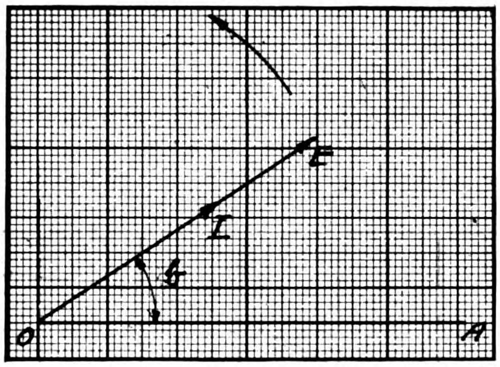


Fig. 5.

As regards efficiency the synchronous motor's superiority is particularly noticeable at speeds less than 600 rpm. At higher speeds the synchronous motor still maintains a considerable margin over the other types of alternating current motors as regards efficiency.

So far we have considered the various types of alternating current motors rather abstractly. For a given installation the step following the selection of the motor type is to decide the size and speed of the motor best suited. The synchronous speed for all alternating current motors is given in the table below:

| | | |
|---|---|---|
| For 2 pole type | 1500 on 25 cycles | 3600 on 60 cycles |
| 4 | 750 | 1800 |
| 6 | 500 | 1200 |
| 8 | 375 | 900 |
| 10 | 300 | 720 |

that is, the number of poles and the revolutions per minute are related as follows:

$$\text{on 25 cycle circuits rpm} = \frac{120 \times 25}{p}$$

$$\text{on 60 cycle circuits rpm} = \frac{120 \times 60}{p}$$

where p is the number of poles.

Induction motors when running free will have these speeds approximately, the difference between this maximum and the actual speed being the amount of slip required to furnish the motor losses. When fully loaded the speed of well known standard makes of squirrel-cage type of motor will be close to 1450 rpm for the 2 pole, 25 cycle machine and 3500 for the 2 pole, 60 cycle machine. The 6 pole 25 cycle will run about 480 and the 6 pole, 60 cycle about 1160 rpm and so on. The above applies roughly to all sizes of machines from 2 up to 200 hp.

In deciding upon the horsepower of the motor to be selected care should be taken to so select the motor that it will be well loaded up at all times because otherwise the effect on the power factor of the line will be needlessly bad. The accompanying plot shows the power factor of a given induction motor under various load conditions.

In writing specifications for motors it is always advisable to go into considerable detail as to the exact use the motor will be put. Where a periodic cycle is involved all details available should be given in order that the manufacturer may supply the motor best suited to conditions.

**The Synchronous Motor..**

Where a synchronous motor is to be used many factors are involved and the selections should be made by an experienced man.

In order to understand the factors that enter the selection, we will first consider some of the simple alternating current circuits. Fig. 1 represents a simple alternating current circuit having only resistance. The heavy line represents the voltage applied and the dashed line represents the resulting current flowing. It is to be noticed that the current follows closely the shape of the voltage curve and crosses the zero line where the voltage line does. It is seen too that it reaches a maximum value when the voltage is maximum. In fact at any instant ohm's law is applicable in the same way as in dc work. The voltage and current are said to be in phase.

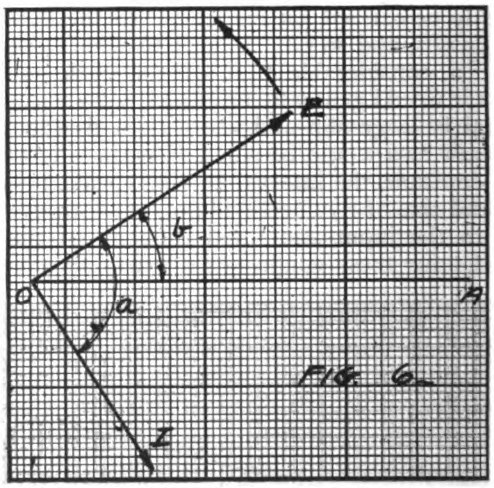


Fig. 6.

It is found that whenever there is a change in the current flowing in a circuit there is an electro motive force) of self-induction induced which opposes the change in the current. If the current is on the increase the induced voltage tends to prevent or retard its increase. When the current flowing is decreasing then the induced voltage tends to sustain the current. This emf is generally large enough to maintain the current between switch contacts for a short interval as they are opened and accounts for much of the flashing that is seen when a switch is opened in a circuit carrying current. The property of an electric current whereby it opposes a change in the current flowing is called self-induction or the inductance of the circuit, the two terms have the same meaning but the term inductance is generally used in engineering work.

If we have now an alternating current flowing in a circuit of negligible resistance but so arranged as to have a high inductance then the curve drawn of applied voltage and current flow would look like Fig. 2. It is seen that the current or dotted line now follows the voltage line by the distance represented by the angle $\frac{\pi}{2}$ or 90 degrees. A mechanical example of the alternating current with resistance only would be that of a rod and two weights arranged as in Fig. 3. $W_1$ here represents the voltage, $W_2$ the current which is forced to oscillate in phase with $W_1$. If $W_2$ is now suspended by a separate rod as in Fig. 4 and is connected to the rod supporting $W_1$ by a coil spring S we then have an example of an alternating current circuit containing inductance. It is seen that $W_2$ is forced to follow $W_1$, $W_1$ being very heavy but that its path will lag that of $W_1$ by a certain angle determined by the spring and other factors. This corresponds to the plot Fig. 2 the distance marked $2\pi$ being the time taken for the weight $W_1$ or E in Fig. 2 to leave the zero line, cross it on the back stroke and reach it moving in the opposite direction. This means that in an inductive circuit the current tends to lag behind the voltage by some definite angle.

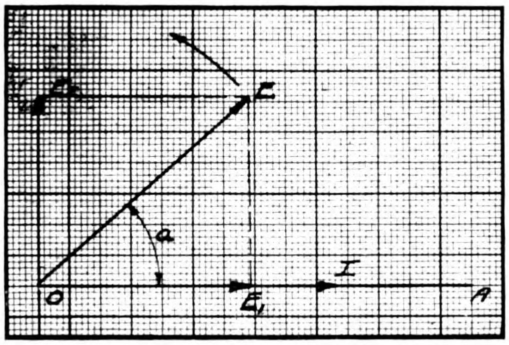


Fig. 7.

In direct current work it is proper to measure the power in the circuit by the product of the voltage by the current flowing. This same method applies to alternating current work for any instant of voltage and current value. Where there is any interval of time elapsing during the measurement, then another factor comes into consideration. This is called the power factor of the circuit. Referring again to Fig. 3, if we let $W_1$ represent the voltage E and $W_2$ represent the current flowing then we can represent conditions in a pure resistance circuit by two superimposed lines or vectors as in Fig. 5. If these are considered to rotate as shown by the arrow they will generate the curve in space shown in Fig. 1.

Again if we have an inductive circuit we can represent the lagging current by the lagging weight in Fig. 4 or by vectors as in Fig. 6. By experiment we find that I lags E by 90 degrees when no resistance is in the inductive circuit. I is superimposed on when resistance only is in the circuit and for intermediate values I lags E by an angle depending on the relation of resistance and inductance.

In Fig. 7 is represented conditions in a given inductive circuit where I lags E by an angle **a**. E may be resolved into two components $E_1$ in phase with I and $E_2$ at 90 degrees or directly out of phase with I. It is the component $E_1$ that is the power component and is called real. The other component $E_2$ is called the reactive component and has no power to do work. It is sometimes referred to as the wattless component.

E × I is called the apparent power of an alternating current and is what is measured by the volt and ammeter method.

$E_1 \times I$ is the actual power and equals $E \times I \times \cos a$, where a is the angle between E and I.

Then the power factor on this basis is the ratio of actual power divided by the apparent power and equals

$$\frac{E \times I \cos a}{E \times I}$$

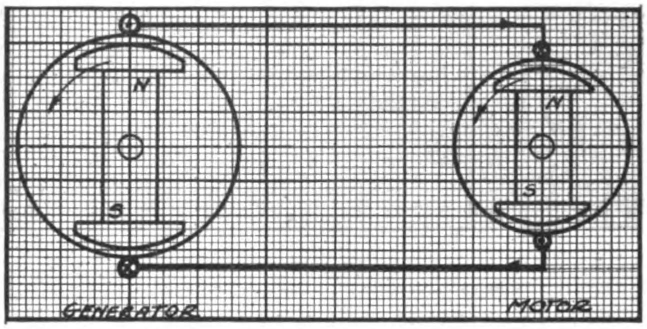


Fig. 8.

That is to say,

The power factor is cosine of the angle between the voltage and the current flowing in an alternating current circuit. A wattmeter takes this power factor into account automatically. When ammeters and voltmeters are used to measure the power in a circuit some means must be used to ascertain the power factor. There are meters on the market that will give this reading directly. The actual power is then the product of the three readings.

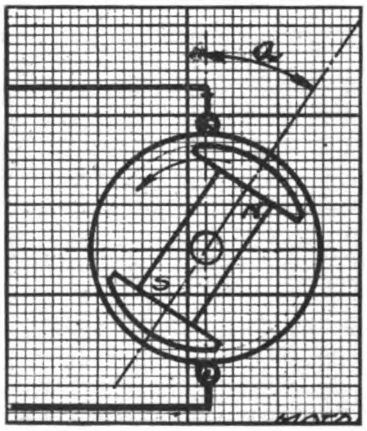


Fig. 9.

The current flowing in the circuit 90 degrees out of phase with voltage is called the reactive current and it accomplishes no useful work, merely surging from a maximum positive value to a maximum negative value, the average work value being zero but any line losses it will be remembered are always proportional to the square of the current flowing and does not take into account the phase angle, etc. This reactive current thus comes in for a full share as far as producing heat losses.

The synchronous motor and the alternating current generator are practically identical as far as designs concerned. In fact the generator can be made to operate as a synchronous motor if supplied with the proper alternating current and proper excitation. To understand the motor and its operation, consider for the moment the simple alternating current circuit. It is seen in Fig. 8, that if a generator and a synchronous motor are connected as shown that if the motor is brought up to the speed of the alternator, i.e., synchronous speed and properly excited with direct current in the coils S and N, then the current flowing in the stator winding will reverse at the proper time to produce a force acting between the poled S and N and the magnetic field set up by the current in the stator winding. It is these forces that produce the rotative effect in the synchronous motor.

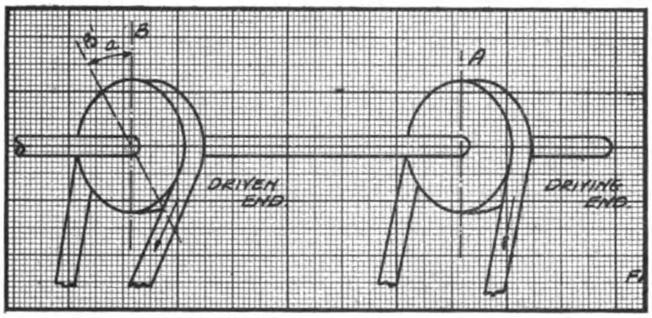


Fig. 10.

When the motor is running with no load, the current taken from the line is practically zero and is merely sufficient to overcome the windage and other friction losses. The back emf of the motor in that case equals the emf of the generator and no current will flow in the line. The poles of the two machines will rotate in the the same relative position as shown in Fig. 8.

If a load is now applied, the motor drops to a position marked B. This means that the back emf $E_2$ of the motor is now no longer exactly opposing $E_1$ but that lags by an angle a, see Fig. 9. The resultant $E_1$ sends a current through the system and develops a torque sufficient to keep the motor at synchronous speed and the angle "a" adjusts itself so that the current flowing will develop sufficient torque to keep the motor up to speed.

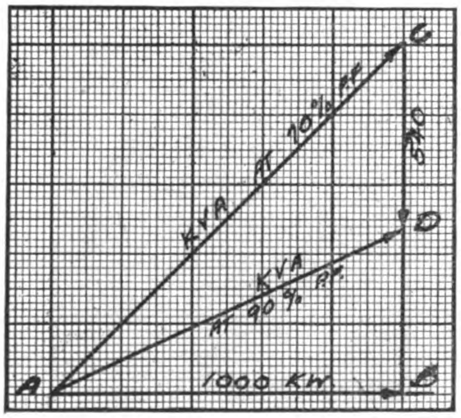


Fig. 11.

The mechanical analogy is found in the line shaft in Fig. 10 here with no load being transmitted, two lines A and B are drawn in the same relative position on the two pulleys. When the load is applied the shaft takes a certain twist depending on the load and B drops back a certain angle. The angle depends on the load transmitted just as in the case of the electrical load. It will be noted that both ends of the shaft still rotate at the same speed, but that B is always just behind.

Fig. 9 shows the motor operating with such excitation of the field that the back emf $E_2$ equals the generated $E_1$. It is evident that the back emf depends upon items, i.e. rotative speed and excitation or in other words upon the number of lines of magnetic force cut per unit of time. If then the synchronous motor is over excited then it follows that the voltage $E_2$ must be greater than $E_1$, see Fig. 11. The resultant voltage $E_3$ draws a leading current from the line by the angle c. This is most important because the leading current if properly applied may be used to cancel some lagging current produced by some other piece of machinery or other line and so improve the power factor of the whole system.

Based on the foregoing we are now in a position to figure synchronous motor sizes for various installations. The graphic method used in what follows is simple and if carefully followed out is reasonably accurate.

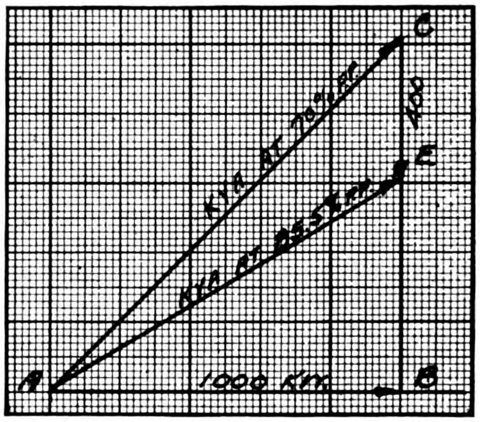


Fig. 12.

The problem of power factor correction by means of synchronous motors generally comes in the following forms:

First—Given a load at a known power factor, to determine the size synchronous motor required to raise this power factor to a new given value.

Second—Given the synchronous motor rating and the load and its power factor, to find the final power factor that can be affected by its use.

Third—Given the synchronous motor rating and the load and power factor correction to be effected, to find the mechanical output that can also be carried.

Fourth—Given the synchronous motor rating and the mechanical load to be carried, to determine the power factor correction that can be effected.

A problem worked out for each of these is probably the quickest and best way to make this clear.

Problem 1. A plant has a number of large induction motors and other apparatus totaling 1000 kw operating at 70 per cent power factor. What size synchronous motor will be required to raise the power factor of the mill load to 90 per cent?

Use cross section paper for plotting these problems when available as the results are more dependable.

Lay out the plant load of 1000 kw along the horizontal, see Fig. 11 as this is a real load. Then at an angle whose cosine is .70 layout the kva line for this load, line ac. In the same way layout AD whose angle DAB is the angle whose cosine is .90. DC is then the reactive load that the synchronous motor must carry. This is then scaled off and amounts to 540 kw.

If the above plant has also available a synchronous motor of 400 kva capacity, what power factor correction could be expected by operating this motor as a synchronous condenser.

Refer to Fig. 12. Layout the 1000 kw and the kva line as in problem 1. From C lay off line CE equal to 400 kva at 90 degrees to the line AB and downward since this represents a leading current. Draw line AE. Angle EAB now represents and designates the power factor. Divide the length AB by the length AE to get the value numerically. The power factor in this case is 85.5 per cent.

Problem 3. Given the load of 1000 kw at 70 per cent power factor and a 500 kva synchronous motor—to find the mechanical output that could be obtained while operating with sufficient over excitation to raise the power factor of the system to .90.

Lay out the 1000 kw line AB and the kva line corresponding to this at 70 per cent power factor, line AC. With C as a center swing the arc with radius equal to 500, the rated capacity of the motor. In this case the arc cuts the line AD extended in two places E and E¹. At either of these points the synchronous motor will give the correction required and the length of the lines FE and FE will represent the capacity of the motor for doing mechanical work. It is to be noted that the motor can give more power factor correction when carrying a mechanical load than when simply acting as a synchronous condenser. Also note that the maximum correction occurs when AE is tangent to the circle whose radius is CE.

Problem 4. Given the load of 1000 kw at 70 per cent power factor and the synchronous motor of 500 kva rating carrying 250 kw in mechanical load, to determine the maximum power factor correction that can be obtained.

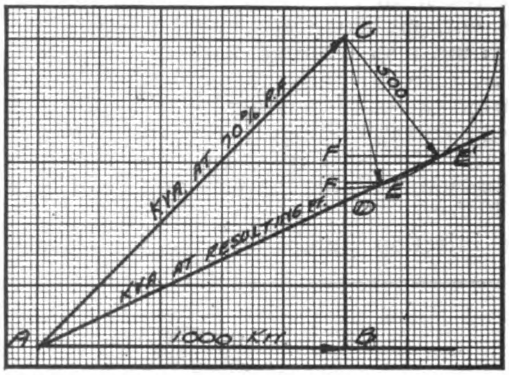


Fig. 13.

This is similar to problem 3. From point C layout the circle as before with C as a center and CE as a radius to the scale of 500. From the line BC lay out the line FE so that FE scales 250. Now draw line AE. The angle AE makes with the horizontal is the angle that determines the power factor.

# Discussion Economic Considerations of Power Plants

## Results Obtained in Recent Investigations Made for the Ingersoll-Rand Company of the Performance of a Number of Their Barometric Condensers.

By **N. E. TAYLOR,** Ingersoll-Rand Company.

THE article by Mr. Keating on "Some Economic Considertaions in Design of Power Plants for Steel Mills", in the October, 1920, issue of THE BLAST FURNACE AND STEEL PLANT, discusses a subject which is always of great interest, i. e., the choice of condensers. However, in considering the relative merits of surface, low level jet and barometric condensers the author has made some assumptions which appear questionable to the writer, who, therefore, would like to submit the following discussion:

For the barometric condenser the loss of vacuum due to friction in the exhaust steam piping between the turbine and condenser is assumed to be .4″ of mercury. Sometime ago the writer made an investigation for the Ingersoll-Rand Company of the performance of a number of their barometric condensers serving turbo blowers and generators in the Pittsburgh district, and in the light of this experience believes the figure given above to be decidedly too high for modern barometric condenser installations. The investigation referred to was conducted during the winter and spring when cold injection water was available and the vacuum was about 29″. Under high vacuum winter conditions the friction loss between turbine and condenser will not exceed .2″ in a properly designed plant. In one instance in a large steel plant with 28.97″ vacuum at the turbine exhaust it was found that the pump vacuum was 29.1″. In the summer with lower vacuum this loss is much less. For example, another reading may be given of 27.98″ at the turbine and 28.05″ at the pump. Therefore, a conservative average figure would be .1″ to .15″.

Secondly the author makes a deduction of 20 feet from the total static head for syphon effect on the barometric condenser injection water pump. In figuring the power required to drive this pump it is advisable, of course, to be conservative, but many successful barometric installations have been based on an allowance for syphon effect of 90 per cent of the vacuum and results equaling or bettering this performance have actually been obtained in many cases. With 28½" vacuum the allowance for syphon effect then would be 29 feet instead of 20 feet, as given by Mr. Keating.

Thirdly, in tabulating the factors influencing the three different types of condensers, the pumping head for the low level jet condenser is given as 44 feet. This is the head on the injection pump, but is misleading without some statement concerning the removal pump also required with this type of condenser. The removal pump is required to withdraw the water from the condenser against a high negative suction head corresponding to the vacuum in the condenser less the positive static head on the removal pump suction, making the net total head in this case about 30 feet.

The injection pumps for the low level jet and barometric condensers and the circulating pump for the surface condenser will each have an efficiency of about 80 per cent. However, the efficiency of the removal pump of a low level jet condenser is seriously affected by the high negative suction head and in this case would be 50 to 55 per cent.

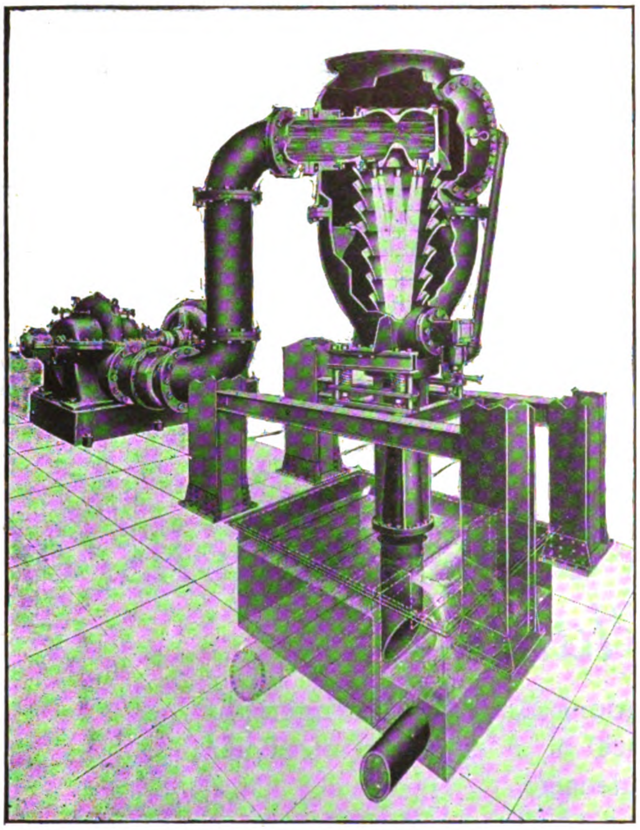


**Fig. 1—Ingersoll-Rand low level multi-jet condensing plant showing condenser and Cameron pump.**

For convenience in comparing the pumping heads of the three types of condensers, the removal pump head of 30 feet with 52½ per cent efficiency can be taken as equivalent to 46 feet head with 80 per cent efficiency. The comparative pumping heads and total bhp required for water pumping based on 12,000 gpm for the barometric and low level jet condensers and 14,000 gpm for the surface condenser will be:

| | Jet | Barometric | Surface |
|---|---|---|---|
| Pumping head (referred to a pump efficiency of 80%............... | 90 | 55 | 56 |
| B. H. P. required by water pumps | 341 | 208 | 247 |

To complete the comparison of power consumptions of the three types of condensers, the air pump requirements must be added in and also the condensate pump for the surface condenser. Mr. Keating has not given his detailed estimates for the power requirements, but the writer estimates that the air pumps for each type of jet condenser will consume approximately 100 hp, and for the surface condenser 50 hp. The vacuum pump hp requirements will vary somewhat with the type of pump used, but for purposes of comparison the figures given should be sufficiently accurate. The condensate pump for the surface condenser would require about eight bhp. This makes the total power requirements of the condenser auxiliaries for each unit as follows:

| | Jet | Barometric | Surface |
|---|---|---|---|
| B. H. P. ......................... | 441 | 308 | 305 |

In arriving at comparative cost data on which the condenser selection is based, Mr. Keating has added fixed and operating charges for the condensers alone to the total fuel costs for the main units and auxiliaries which is rather confusing when the purpose of the comparison is to help in the choice of condensers only. In the table given below the writer has taken the initial costs and operating charges given by Mr. Keating and has added the cost of the power required to operate the condenser auxiliaries at the rate of one cent per kw per hour at the switchboard, assuming an overall motor efficiency of 85 per cent, in order to get comparative costs of producing the vacuum independent of main unit costs.

Fixed charges are added in at the rate of 20 per cent instead of 15 per cent used by Mr. Keating, as the latter figure is inadequate to take care of present day interest and depreciation charges.

| | Jet | Barometric | Surface |
|---|---|---|---|
| Water required, gal. per min. per unit | 12,000 | 12 000 | 14,000 |
| Pumping head in feet............... | 44 | 55 | 56 |
| (Removal pump) ................ | 30 | .. | .. |
| Total installation cost including condenser, condenser auxiliaries, pump house, water treating plant........ | $312,000 | 280,000 | 345,000 |
| Fixed charges 20 per cent............ | $ 62,400 | 56,000 | 69,000 |
| Operating charges: | | | |
| (a) Water treating plant.......... | $ 17,000 | 17,000 | 2,500 |
| (b) Tube maintenance............. | ..... | ..... | 10,800 |
| (c) Pump maintenance ........... | 2,000 | 2,000 | 2,100 |
| Total fixed and operating charges.... | $ 81,400 | 75,000 | 84,400 |
| Costs of power for driving condenser auxiliaries based on generating 112,000,000 kw hours per annum.... | $ 57,800 | 40,500 | 40,100 |
| 1% of main unit fuel costs allowance for friction loss of vacuum approximately ...................... | ..... | 3,000 | ..... |
| Total annual costs of producing vacuum ......................... | $139,200 | 118,500 | 124,500 |

On the basis of this comparison the low level jet condenser seems to be least suited for this installation. The reason for this is obviously the higher pumping head required, amounting to 50 per cent more than in the case of the barometric, as shown in the preceding table of comparative pumping heads. The higher head, of course, results in more power required and greater annual cost.

If the loss of vacuum between turbine and condenser for the barometric condenser were on the order of .4", the loss of economy on the main unit might possibly over balance this difference in auxiliary

(Continued on page 693)

# Heating Furnaces and Annealing Furnaces

## The Labor Saving Features of Different Types of Furnaces Are Discussed—Batch Furnaces—Various Types of Continuous Furnaces.

By W. TRINKS.

PART XXIV.

IN furnace work, saving of labor is just as important as saving of fuel, and perhaps even more so in the United States, because our fuel resources are still so plentiful as to make fuel cheap compared with labor, no matter what the price of the latter may be.

It stands to reason the method of handling material through furnaces must vary with the shape, temperature and size of the material. The work is comparatively simple in the so-called steel industry, that is to say in the rolling mills, because the shapes to be heated are those of semi-finished material and are very simple, being mostly rectangular. On the contrary, works producing finished material of complicated shapes experience more difficulty for reasons which will be explained below.

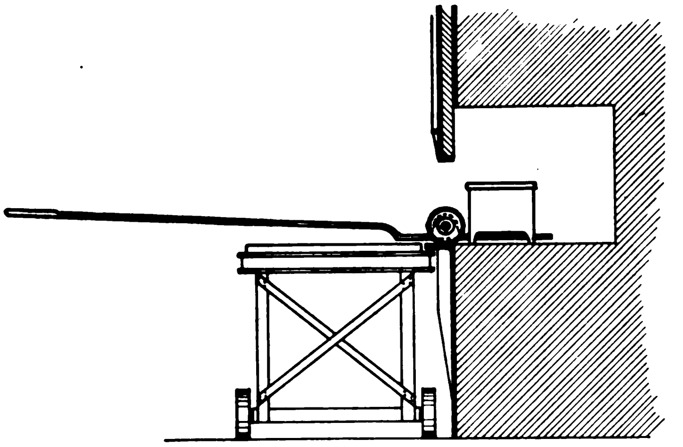


Fig. 177.

The handling of the material varies with the type of the furnace, the two principal types being the "in-and-out" or batch furnace and the continuous furnace.

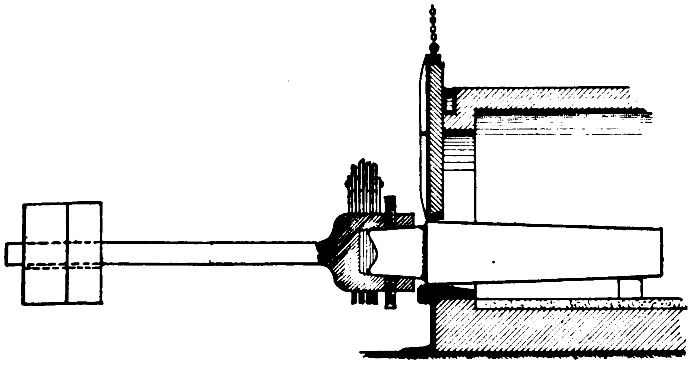


Fig. 178.

In the former type there is but little which the furnace designer can do to make the handling of materials easier and cheaper, except by making doors of sufficient size, by making them move easily, and by building the door jambs and frames strong enough to withstand rough handling. Furthermore, he can arrange the path and pressure of the products of combustion so that no flame blows into the face of the operator when the door is opened.

The handling itself is done with tongs for pieces weighing up to 40 or 50 pounds. Heavier bars up to 400 or 500 pounds are handled with tongs which are suspended from monorails. Still heavier blooms or slabs are handled by manipulators or charging machines, or else by tongs suspended by cranes. Several firms in the United States make a specialty of charging and drawing machines. Their description lies outside the range of this series of essays.

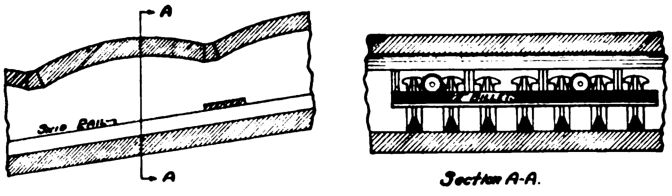


Fig. 179.

Small pieces in quantity are frequently shoveled into the furnace with a pitch fork and are pulled out with a rake. Or else they are placed in trays or boxes which are handled by charging machines, or by wheeled forks, see Fig. 177.

Going to the other extreme, we find that heavy ingots for forge work are handled by means of porter bars suspended from cranes, Fig. 178. Ingots with porter bars must be handled with extreme care and slowness, because sudden stopping of the crane carrying a fast moving ingot with porter bar produces a long forward swing. The ingot strikes the furnace walls, or the chain strikes the door, and the brick layers are kept busy. In some forge shops the repair

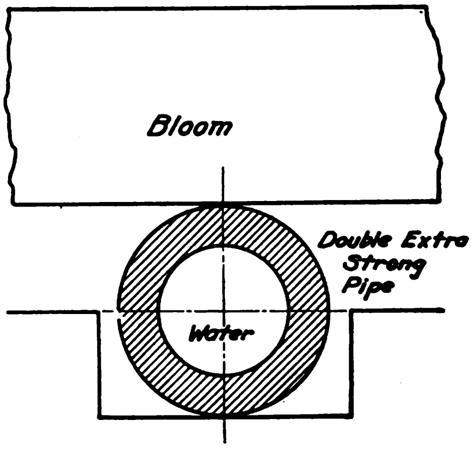


Fig. 180.

bills have been reduced by the installation of a projecting apron just above the door. The heaters dislike these aprons, because they do not allow the crane chains to come close to the furnace door.

Ingots for rolling mill work are heated vertically in pit furnaces and are handled by stiff leg cranes with tongs. Occasionally they are handled by tongs suspended from ordinary crane chains; this method is unsatisfactory, because of the swinging of the ingots. The work requires in addition to the crane operator, another man who guides the ingot and stops the swinging motion.

In part XIII, mention was made of bung top furnaces, that is to say, furnaces with removable roof. They are used wherever horizontal handling of the stock is less favorable than vertical handling.

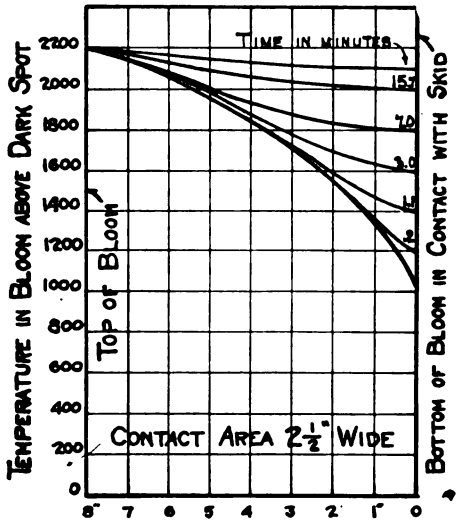


Fig. 181

The ideal way of heating and of handling material is found in the use of the continuous furnace. The general type has two subdivisions, namely, the straight line type, and the rotating hearth furnace. By far the greatest number of continuous furnaces are of the straight line type. Material is moved through the furnace in various manners, namely

1. By pushing the stock over a fixed hearth.
2. By pushing trays, containing the stock, over a fixed hearth.
3. By resting the stock on movable cars which are pushed through the furnace.
4. By disappearing rocker bars which, at intervals, lift the stock off the hearth and deposit it a given distance further along.
5. By carrying the stock through the furnace on an endless chain passing through the furnace.
6. By carrying the stock through the furnace on an endless chain passing through open channels under the furnace hearth.
7. By rolling round material down an inclined hearth.
8. By passing flat material over rollers in the furnace hearth.
9. By pulling endless material, such as wire, through the furnace.
10. By forming the interior of the rotating furnace in the shape of a helix and causing the helical ribs to carry the stock along the axis of the furnace. (See Fig. 96, January, 1920, issue).

Method No. 1, namely pushing the stock over a fixed hearth is the standard for moving square bars, billets, blooms and heavy slabs through furnaces. For reasons of fuel economy, continuous furnaces are seldom shorter than 20 feet and for operating reasons they are seldom longer than 50 feet. In long furnaces, the high temperature zone extends back a greater distance than it does in short furnaces. The result is that in 2200-degree F. furnaces, pieces which are short in the direction of the pusher motion, will be sticky at a place where the pressure between the pieces of steel is still quite great; they will therefore be hard to separate at the exit. In consequence of this limitation, furnaces heating 2" x 2" billets can not be made as long as furnaces heating 2½" x 20" slabs or similar shapes. Some continuous furnaces of the pusher type have been made with hearths slanting upward towards the hot end, others have been built with horizontal hearths, and still others with hearths sloping downward toward the hot end. A moderate downward slope (downward toward the hot end) is desirable, because there should be atmospheric pressure in the furnace along its entire length. The chimney action of the upward traveling gases should be just enough to overcome their frictional resistance at normal rate of heating.

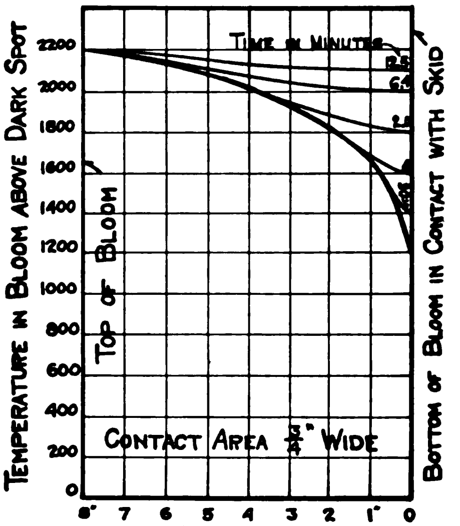


Fig. 182.

The construction of the hearth presents problems. They were mentioned in parts X and XX. Safety and certainty of delivery demand hearth bars upon which the heated material can slide. For thin material, say up to 2½ inch thickness, heat is imparted to the steel from above only, and the hearth bars can be simple rails of steel, see Fig. 179. In this furnace the pressure between the heated steel and the stationary rails equals seven pounds per square inch. The rails are preferably made of an alloy steel which will not oxidize as quickly as plain carbon steel. In furnaces for bigger sections, the flame is split and the rails are exposed to high temperature. In that case it is not only customary but necessary to water-cool the rails. Frequently the rails are simply two-inch double extra strong pipes; they are then called pipe skids, Fig. 180. As long as the pipe is new and but little worn, the contact between steel and pipe is narrow, and heat transmission is limited; but as soon as wide flat spots have been worn on the pipes, heat transmission is very active, first, because the heat conducting surface is larger, and second, because the wall between the water and the bloom is thinner.

A theoretical investigation of the "black spot" which is produced by the water-cooling proves to be very interesting. Figs. 181 and 182 shows the theoretical temperature distribution in an 8-inch bloom for a 2½-inch wide contact and for a ¾-inch contact. In both cases the wall between the bloom and the water is supposed to be ⅞-inch thick. Several temperature lines are given for different lengths of time after removal of the bloom from the skid. From these temperature curves, two time-temperature curves for the center of the black spot were derived. They are shown in Fig. 183. It is immediately visible that a wide black spot is indeed black, and takes a very much longer time for its recovery. The term width is only relative and really should be replaced by the ratio of width of contact to thickness of billet, slab or bloom.

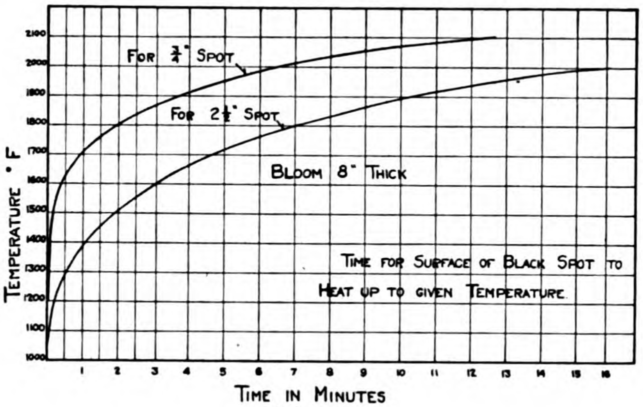


Fig. 183.

When pipe skids were first introduced, the black spots worried mill engineers considerably, and many complicated schemes of forehearths and of secondary pushers were introduced. From the above given curves it is, however, quite evident that the pipe skids should be equipped with narrow tops. If the wearing strength of steel of 1200 degrees F. is taken as low as 125 pounds per square inch, the necessary supporting width (that is to say the sum of the widths of the skids) will equal thickness (inches) x length (inches) divided by 450. A narrow width may be obtained, for instance, by welding strips onto a pipe as shown in Fig. 184. The top strip should not be exposed to an exceedingly hot, oxidizing flame, because it will not last in that case. The flame must be reducing or neutral, or else the strip must be protected by refractory material.

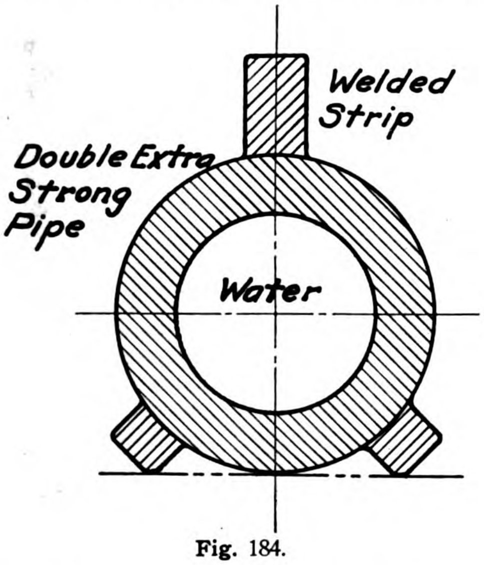


Fig. 184.

It is of course unnecessary to wait until the dark spot has reached exactly the same temperature as the rest of the billet, but it should be so placed as to be at the top, when the billet reaches the mill.

In general, continuous furnaces result in the saving of labor, although this need not necessarily be so. As a rule, one man is required to charge the steel at the cold end while another is required to take the steel out of the furnace. In an "in and out" furnace, one man with a charging machine can attend to the work, but he cannot deliver the steel as regularly as the continuous furnace can, particularly if two or more furnaces heat the steel, and such an arrangement is desirable on account of more uniform heating. In that case a heater is required, while, with the continuous furnace, the attendant at the discharge end can regulate the fire. The desire to save labor was the principal reason for introducing the gravity discharge, (Fig. 170, October 1920) which drops the billet or slab automatically on a conveyor leading to the mill. But even with this device a man at the discharge end can hardly be spared, first, because the fires need attention, and second, because the billets are perverse enough to come out one sided and to get stuck across the conveyor so that some persuasion with a hook becomes necessary. Furthermore, it is desirable to turn them with the black spot up. Nevertheless, the continuous furnace in combination with a roller conveyor, not only saves labor, but also

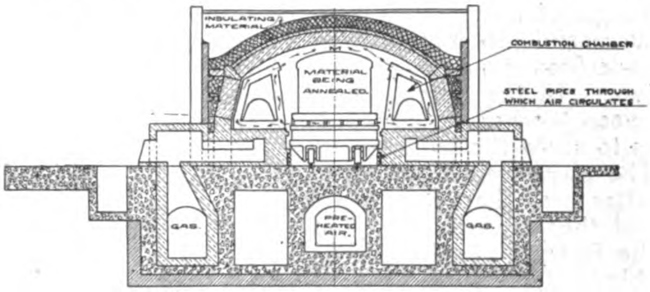


Fig. 185.

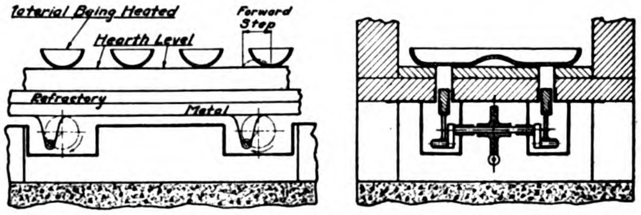


Fig. 186.

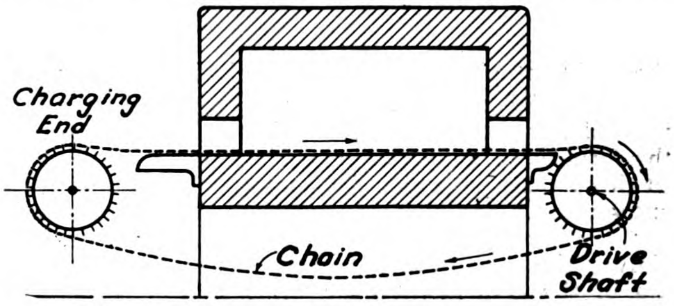


Fig. 187.

delivers more uniformly heated billets, with a small amount of scale. It is used wherever possible.

The second method, namely that of pushing trays, containing the stock, over a fixed hearth, is very commonly used in annealing furnaces or tempering furnaces for odd shaped materials. The method shares one disadvantage with all tray methods, namely that the heat in the tray is lost. With proper design of hearth bars and trays the method is very successful, no matter whether the furnace is of the underfired type or of the whirling-flame side fired type. In the latter case there must be a space between the hearth bars and the bottom of the tray so as to allow the hot gases to wash all around the tray. The trays are moved around the shop on trucks; the latter are wheeled into a space between the furnace and the pusher and are pushed from the truck into the furnace. In heat treating work, it is not advisable to dump a whole tray full into the bath, because the different pieces are not quenched uniformly.

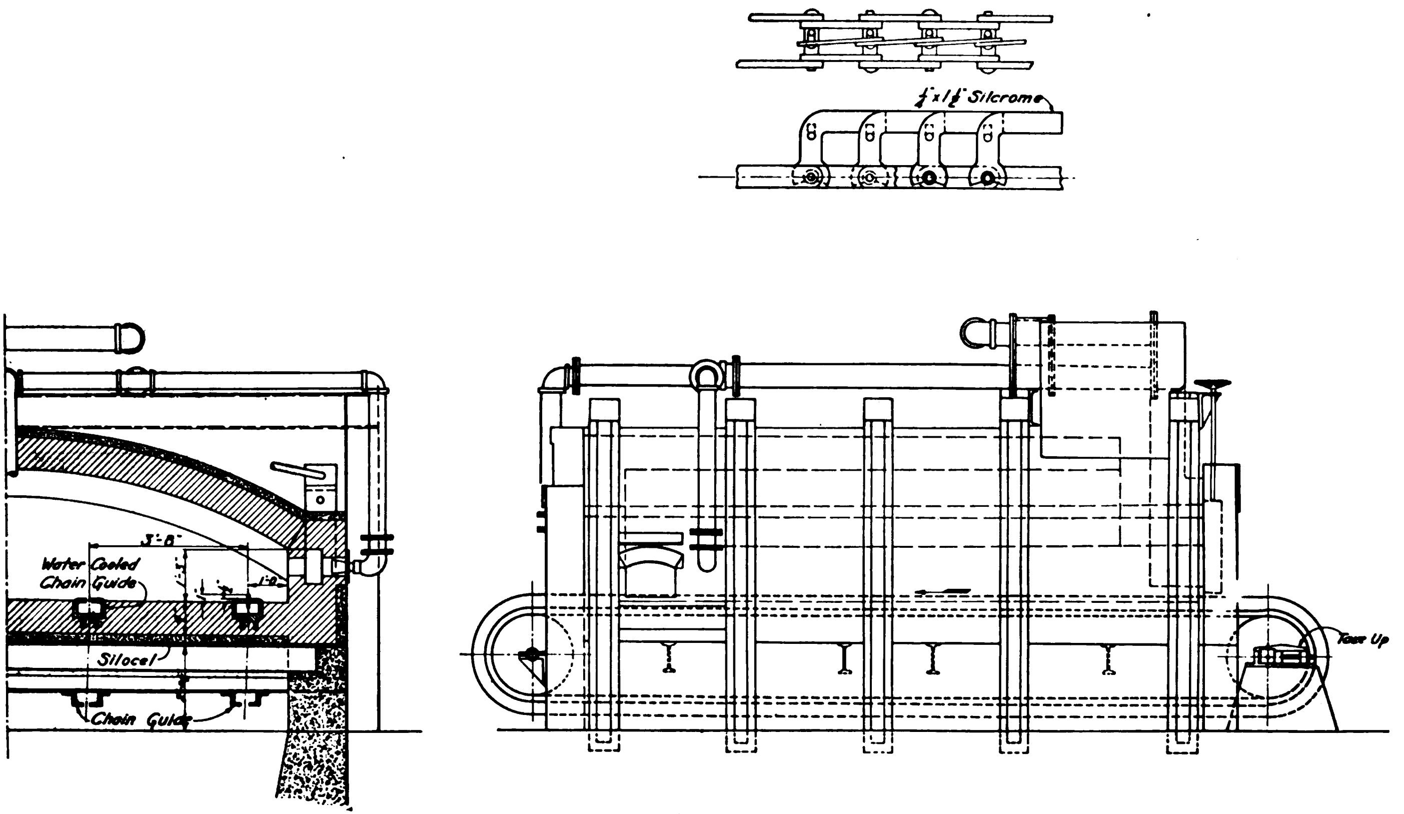


**Fig. 189.**

The third method, namely to rest the stock on movable, individual cars, which are pushed through the furnace, is employed in special cases. It is limited to those cases in which the material is not of sufficiently rectangular shape to allow direct contact pushing. In high temperature work, (2200 degrees F. and above) the construction of the cars and the tightening of the cars against the walls as well as against each other, offer difficult but by no means unsurmountable problems to the designer. Other problems involve quick transfer of the car from one end to the other for the purpose of saving some of the heat in the brickwork, and the prevention of chilling of the charge, which must be right up against the discharge door (in order to avoid excessive length of car for a given length of charge). The individual car method has been brought to a high stage of perfection in the tunnel kilns. Although these furnaces are largely used for the annealing of sheets, the name "kiln" sticks to them, because they were first developed for use in the ceramic industries; Fig. 185 shows a section through the furnace. The space below the car is hermetically sealed, so that no flame or hot products of combustion can creep under the car. The hermetic sealing is insured by an air lock at either end of the car. Furnaces of this type have been built with lengths of 160 feet and more.

The fourth method, involving the use of disappearing rocker bars which, at intervals, lift the stock off the hearth and deposit it a given distance further along, has always been popular with inventors. It has been less popular with the users. The reasons for both statements are evident from the diagramatic illustration, Fig. 186. Pieces of a wide range of shapes and sizes can be handled; they can be placed close together or far apart at the will of the operator. On the other hand, the slots in the hearth make it extremely difficult to obtain a uniform temperature of the stock to be heated; and it is a serious problem to maintain the operating mechanism without excessive cost of repairs. Furnaces are always operated with a slight pressure, and the flame tends to work into the mechanism. The latter must be kept cool. In consequence, the hearth is colder than the walls or roof. Irregularities in the hearth cause the stock to wander off to one side. Repairs to the mechanism are slow and costly. Flow of heat into the cold mechanism adversely affects fuel economy. A few, but very few, of these furnces have been successful for special purposes, but as a general rule, furnaces with "fins and gills" underneath should be avoided.

The fifth method, namely to move the stock through the furnace on an endless chain passing through the furnace, is limited to its scope to annealing and tempering work (1600 degrees F. or below). From part XIX it is quite obvious that the strength of steel at 1600 degrees F. lies considerably below its cold temperature value, and that oxidation plays an important part. For that reason, conveyor or chain types of furnaces are excellent for 1200 degrees F. work, good for 1400 degrees F. work, tolerable for 1600 degrees F., work and useless for higher temperatures, unless heat resisting (and expensive) alloys are used for the conveyor. The conveyor chain becomes longer, as the temperature rises. The expansion can be taken care of by increasing the sag between the sprocket wheels, see Fig. 187. The teeth of the sprocket wheel and the indentations on the conveyor chain must be so designed that the chain will not climb on the wheel. A fine pitch is desirable.

The chain type of furnace (automatic furnace) saves a great deal of labor for certain classes of work. A prerequisite is uniform size and thickness of material to be heated at one time. The automatic furnace is limited to comparatively light work, on account of the weakness of the heated conveyor.

Occasionally, heavy conveyor chains are used with great success to carry light disks or cups through the furnace. In this case, the thin material which is to be heated rests on renewable points of the chain. The chain proper is so heavy that it does not even become red hot. The above mentioned success refers to labor economy, but not to fuel economy.

The sixth method was invented to overcome the drawback caused by a hot chain. The chain proper lies under the hearth, see Fig. 188 (General Combustion Co.) and is not exposed to the high heat. It carries projections of heat resisting alloy which reach up into the furnace. The stock which is to be heated is carried either directly upon these projections, or else upon cross bars (likewise of heat resisting alloy) which are fastened to the projections. Keeping the chain cool involves the limitation that the furnace cannot be of the under fired type. On the other hand, the chain is not weakened by the high temperature, is not oxidized so rapidly and gives less trouble from heat expansion.

Furnaces with conveyors or chains wholly outside the furnace are commonly employed for those pieces which are to be heated at one end only. Pliers which are to be heated at the grip for hardening purposes, tubes which are to be heated at one end for crimping or other forming, and many other materials are very successfully carried through furnaces on outside chains, as indicated in Fig. 189. (Rockwell). The saving in labor in this type over any other type is very marked indeed. It is understood that the type in question can be used only for quantity production.

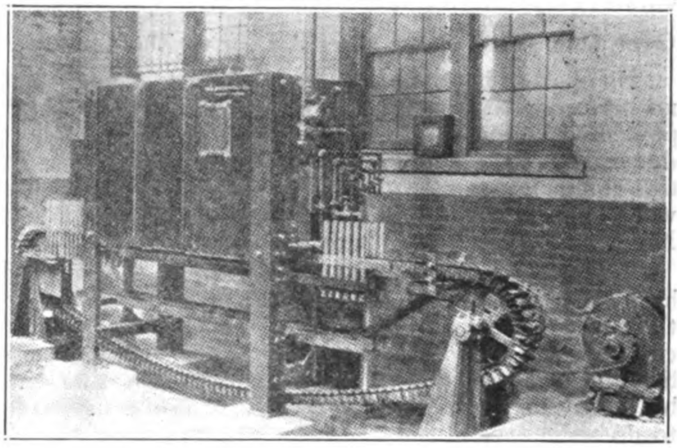


Fig. 188.

The other methods as well as rotating hearth furnaces will be discussed in the next essay.

# Saving Fuel By Controlling Chimney Losses

## Saving of Fuel Very Important on Account of High Cost and General Scarcity—Loss Up the Chimney Always Largest Individual Factor.

By F. F. UEHLING,
Combustion Engineer, New York.

THE subject of fuel economy is today of greater interest to the fuel consumer than ever before. There are two reasons, first, fuel costs two or three times as much as it did a few years ago, and second, it has often been very difficult to get at any price during the past few years. The first reason is one that will remain. Prices of fuel, no matter what kind will undoubtedly stay high, and in all probability will go still higher. The second reason, however, should vanish entirely when once labor and transportation facilities are properly controlled .

There is plenty of fuel for all who need it. The fuel given us by nature ready for use, will last for generations, but even when all our mines are exhausted and our oil fields pumped dry, there will be enough fuel in one form or another. Mother Nature will at that time again come to our protection with that greatest of her laws, the conservation of matter and energy. Carbon and hydrocarbons are really conserved by her unseen hand, but it remains for man to turn the key which will unlock her great storeroom.

The high cost of fuel therefore provides the principal incentive to save it and the greater the cost the greater will be that incentive. The principal factors which enter into the cost of fuel are labor and transportation. Its price to the consumer will be governed by these two charges, plus whatever additional charge competition will permit the mining interests to add. As our resources are depleted, mining will become more difficult and as production moves farther away from consumption, transportation charges are bound to increase. The price of fuel will therefore

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Paper delivered before Fuel Section of the Sixth National Exposition of Chemical Industries, New York, September 21, 1920.

advance from year to year until finally it will be cheaper to make artificial fuel, such as alcohol. In all probability, however, the cheapest fuel for our principal needs will be that which can be gotten out of the ground, as long as it lasts, in its ready-to-use form. That is why it should be made to last as long as possible through the practice of economy. However, since the price of fuel in the future does not seem to interest the present generation, the elimination of unnecessary waste should perhaps even be enforced by law for the benefit of posterity.

### Over One-Third of the Fuel is Lost up the Chimney.

No matter how the fuel we use is consumed and no matter what kind of fuel is burned, whether solid, powdered, liquid or gaseous the biggest loss is always due to the heat energy wasted up the chimney. In this connection it might be well to quote the following very conservative statement from Technical Paper No. 205, issued by the Bureau of Mines:

"In the average boiler plant, 35 per cent of the heat in the coal burned under the boilers is lost with the stack gases. That is, out of every 100 tons of coal burned under the boilers, the heat of 35 tons literally goes up the stack. It is this loss that can be greatly reduced and every effort should be made to do so."

Figures which are reproduced from the same government bulletin, show the magnitude of fuel waste in steam boiler practice and show that the most important part of it is due to the loss up the chimney. According to the speaker's experience, however, this loss in the average plant is not less than 40 per cent and in many cases approaches 50 per cent of the total heat energy in the fuel used.

The loss up the chimney, which is always the largest individual loss in any plant, depends for its magnitude on three factors. They are, in order of importance, first, excess air in the products of combustion; second, temperature of the products of combustion; third, amount of unconsumed fuel in the products of combustion.

### Greatest Loss Due to Using Too Much Air.

The excess air in the products of combustion results in a loss greater than that from any other source. Each kind of fuel requires a definite amount of air to burn it, the exact quantity depending principally upon the ratio of its carbon and hydrogen. When considering coal, for example, the principal constituent is carbon, every pound of which requires twelve pounds of air to completely consume or oxidize it. All air that is used above this amount is known as excess air, and when supplied in greater quantities than is necessary to meet the particular conditions of the furnace in which the fuel is burned, an unnecessary burden is immediately placed on the temperature possibilities of the furnace and the amount of fuel consumed to accomplish a desired result increases in proportion.

Even in fairly good practice, about twenty-five tons of air used to burn one ton of coal, and in the more poorly operated plants, this amount is often doubled. Twenty-five tons represents a lot of air. Under normal conditions, it occupies a space nearly 16,000 times as large as the coal which it consumes. If the amount of air generally used to burn one ton of coal were contained in a pipe with one square foot cross sectional area, it would have to be long enough to extend nearly from New York to Baltimore. Stated in another way, if the floor of a room were covered with coal to a depth of one foot, the ceiling would have to be over three miles high in order for the room to contain as much air as is generally used to burn that quantity of fuel. The fact that so much air is consumed in burning coal is not realized by the fireman and the important relation which this huge mass bears to fuel economy is generally not given sufficient thought by his superiors. Although air costs nothing, and is available in unlimited quantities, when used to burn fuel in excess of what is required, as is the case in the average plant, it becomes one of the most expensive raw materials.

All the air that is used in burning fuel, whether under steam boilers or for any other process, appears in the products of combustion. If three times as much air is used as is necessary there will be just about three times as much products of combusiton as necessary. The gas as it passes up the chimney contains the major portion of the heat that is unnecessarily wasted. The exact amount of heat wasted in this way can be determined by the weight of the products of combustion per pound of fuel burned, and the temperature at which they leave the furnace or enter the stack. Thus, in the average plant, from one-third to one-half of the heat contained in the fuel is stolen by the products of combustion and dissipated into the atmosphere.

### Smoke Not Necessarily a Sign of Waste.

The other loss up the chimney, namely that due to unconsumed fuel in the products of combustion, is usually not so serious. The old idea that a smoky stack is a sign of tremendous waste is not always true, in fact, whether the gases leaving a chimney are smoky or smokeless is no indication at all as to the efficiency with which the fuel is consumed. Steam boilers, for example, connected with a stack that does not show the slightest trace of smoke may burn twice as much coal per pound of steam generated as when smoke is in great prominence. Black smoke is of course unburned carbon, but the amount of carbon in this light and finely divided form that is necessary to give the products of combustion a dark or even a black appearance is generally only a small fraction of one per cent of the actual fuel burned. The additional unconsumed fuel that is apt to be present in the products of combustion is carbon monoxide and hydrocarbons, both of which are caused by an insufficient air supply or the improper mixture of the air with the fuel before it is ignited. Although it is possible for the loss due to this cause to be serious, it is a fact that the average loss from this source can safely be estimated at less than two per cent.

### Instruments Detect Chimney Losses.

It is not the object of this paper to discuss any particular method of burning fuel. To minimize chimney losses, no matter what means is used, we must know whether or not the proper amount of air is being supplied, whether or not air is mixed with the fuel before it is ignited, and whether or not too much heat is left in the products of combustion as they pass up the chimney. Under all conditions these important facts can be determined by consistent flue gas analyses and temperature measurements. Insofar as stack losses are concerned, the effect of any change in fuel or method of firing, the results of any additions or changes, or the value of any new appliance, can in this way be determined at once, and the best efficiency under the working conditions of any plant can generally be obtained and maintained without the necessity of lengthy and elaborate tests.

In ninety-nine cases out of a hundred, excessive loss of heat up the chimney is simply due to lack of facilities for determining whether the proper amount of air is supplied. When carbon, the principal constituent of any fuel, is completely burned the result is carbon dioxide ($CO_2$). Complete combustion occurs when air is supplied in excess of what is needed. When, however, the air supply is reduced too much so that it is little more than that whic his theoretically required, there is also a possibility of incomplete combustion due to an insufficient amount of air reaching part of the combustible. When this is the case some of the carbon in the fuel will become only half oxodized, that is, it will burn to carbon monoxide (CO) instead of to $CO_2$.

### Carbon Dioxide in Flue Gases the Key to Wasteful Air Supply.

It must be remembered however that the big loss in practice is due to excess air and not to an insufficient supply. In order to clearly illustrate the importance of this fact, let us consider carbon as the fuel we are burning. Since carbon is the principal constituent of all fuels, the same reasoning will also apply to any other fuel, the principal difference being that the maximum obtainable percentage of $CO_2$ is less when fuels higher in hydrogen are used, due to the fact that hydrogen consumes oxygen to form water vapor ($H_2O$) instead of $CO_2$. Thus if one pound of carbon were consumed with the exact amount of air required to completely burn it, the twenty-one per cent of oxygen in the air used would combine with it and appear as twenty-one per cent $CO_2$ in the products of combustion for the reason that oxygen combines with carbon to form an equal volume of $CO_2$. On the other hand, if the same weight of carbon were consumed with twice the amount of air theoretically required to burn it, only one-half of the twenty-one per cent of oxygen in the air used would combine with the carbon, the volume of the products of combustion would be twice as much, and the $CO_2$ content only ten and one-half per cent. Again, if the same weight of carbon were consumed with three times the theoretically required air, only one-third of the twenty-one per cent of oxygen in that air would combine with the carbon, the volume of the products of combustion would then be three times as great as theoretically necessary and the $CO_2$ content only seven per cent. It therefore follows that the lower the percentage of $CO_2$ in the products of combustion the greater will be the volume or weight of the flue gases per pound of fuel burned, and the greater the temperature of this gas as it leaves its zone of usefulness the greater will be the loss per unit of its weight. In average steam boiler practice, for example, every pound of flue gas it passes up the chimney is laden with sensible heat energy to the extent of from 100 to 200 heat units, and since there are from 25 to 30 or more tons of flue gas for every ton of fuel consumed, the magnitude of this tremendous loss can be readily appreciated. What it amounts to in actual heat units or in percentage of fuel used depends upon the percentage of $CO_2$ and the stack temperature. A table based on carbon as the fuel burned is shown in Fig. 1. Such a table can be prepared for any kind of fuel. With fuels such as oil, which are high in hydrocarbons, the maximum percentage of $CO_2$ obtainable would be less, but every one per cent drop in $CO_2$ would mean a greater increase in fuel wasted than a corresponding drop in $CO_2$ where a fuel richer in carbon is used. The percentage of $CO_2$ in the products of combustion is therefore an index to the amount of air used per pound of fuel burned, no matter what commercial fuel is utilized. Chimney losses can thus be controlled, at least to the extent which the particular design of furnace will permit, by the simple regulation of the air supplied, so that the weight of the products of combustion per pound of fuel burned will be reduced to a minimum. The two most important constituents of the products of combustion, for determination by flue gas analyses, are, therefore, the percentage of $CO_2$ and the percentage of CO. The former should be made continuously by means of a $CO_2$ recorder, while the latter determination is only necessary when the percentage of $CO_2$ is so high that an insufficient supply of air to all or part of the fuel is suspected.

Chimney losses, as previously stated, depend upon three factors, the amount of excess air in the products of combustion, which is determined by the percentage of $CO_2$; the amount of unburned fuel in the products of combustion, the magnitude of which is indicated by the percentage of CO; and the temperature of the products of combustion, which can be determined with an ordinary flue gas thermometer inserted in the last pass of the boiler furnace, just before the gas enters the stack.

Of these three determinations the percentage of $CO_2$ is by far the most important. The percentage of $CO_2$ is something the fireman can easily regulate. If the brick setting of a furnace or of a boiler is made tight to prevent air infiltration it is an easy matter for him to decrease the excess air supply ot 50 per cent or less by simple cut and dry methods in the regulation of draft, thickness of firebed, etc., even though the excess air supply may have been 200 or 300 per cent before he attempted to so regulate combustion.

The determination of the percentage of CO, being generally of much less importance, need be made only when there is reason to believe that incomplete combustion exists. In fact the majority of plants where $CO_2$ recorders are used, get remarkably good results, in so far as economy is concerned, without making CO determinations at all. In other plants, a series of tests are run for determining the maximum safe percentage of $CO_2$ without the formation of CO and the firemen are instructed to keep the $CO_2$ as near this point as possible without exceeding it. In many plants, however, the practice of merely instructing the firemen to keep the percentage of $CO_2$ as high as they can has led to surprisingly good results .

### Low Temperature and Small Volume of Chimney Gases Desirable.

The third variable, namely the temperature of the products of combustion as they enter the stack, is one over which the firemen have no control at all. This temperature should of course be kept as low as possible, but it depends entirely upon how much of the heat in the furnace is absorbed or utilized before the products of combustion make their final exit. In boiler practice, for example, stack temperature depends upon the area of the heating surface over which the hot gases pass and the cleanliness of the heating surfaces. The lower the stack temperatures, the less will be the heat wasted; on the other hand the higher the percentage of $CO_2$ the less will be the volume of

(Continued on page 689)

# Study of the Testing of Welds

## In Determining the Strength of Oxy-Acetylene Welds the Bend Test Is One of the Most Important—Microscopic and Macroscopic Study of Welds.

**By S. W. MILLER.**

THE question of testing welds is one that has been considered more or less since welding was known, but especially during the past five years. Its importance has now became very great. There have been many failures in the past, many of them not having been explained and some of them having been very expensive. As in other developments, welding first received its principal impetus from the practical man. Of late, however, the tendency has been to investigate more carefully and more fully and by means not available to the ordinary welder. This means that scientists of all kinds have been called into consultation and that almost every conceivable method of test has been suggested in order to determine what methods and materials would make the best welds both from a standpoint of security, service and cost. While some of the methods employed at present are beyond the reach of the ordinary welding shop yet they are of great value and, in fact, necessary in order to determine correctly what has occurred during the welding shop operation and what results may be expected under given conditions. Serious criticism of most of the published results can be made because of their incompleteness in one or more respects and one of the things that the American Welding Society proposes to do is to put the testing of welds and welded structures on a firm and safe foundation.

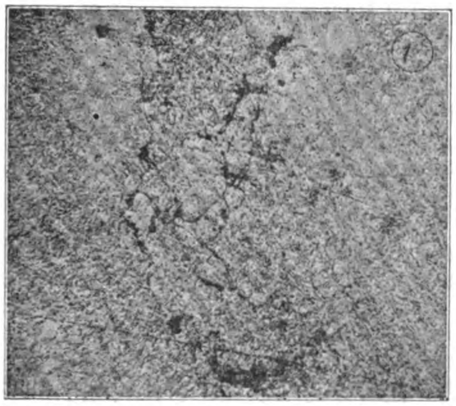

**Fig. 1—Flaky gun steel. Films of oxide or slag, which weaken the metal, and prevent it passing test.**

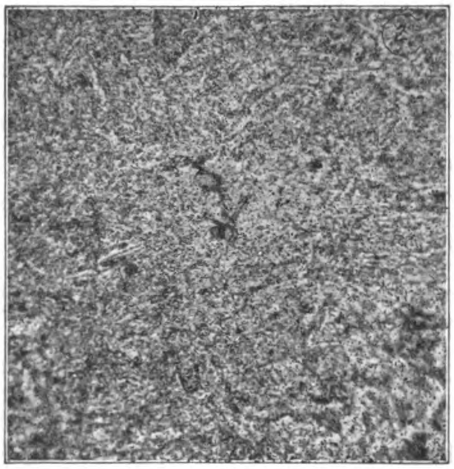

**Fig. 2—Strained piece of gun steel showing rupture beginning at small defects, two small dots of manganese sulphide.**

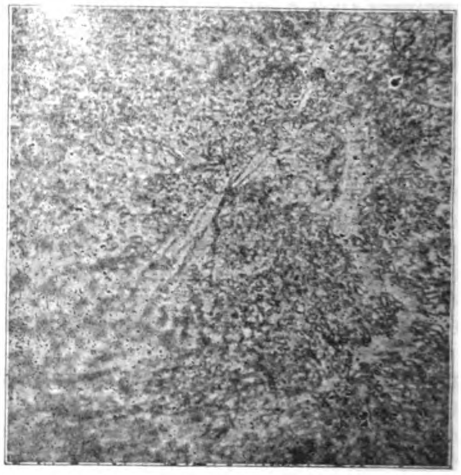

**Fig. 3—Another piece of strained gun steel. Rupture occurs here in a streak of ferrite, which contains no carbon, and so is weaker than rest of the material.**

The testing of metals aside from welds, is quite well developed both in theory and practice. The usual test is the tensile that gives the tensile strength per square inch, the yield point or elastic limit in pounds per square inch, the elongation in per cent of the original gauge length and the reduction of area in per cent of the original section. Compression, torsion, shock and alternating stress tests are also used and the two latter are beginning to be used much more than they have in the past because it has been found that materials may give high results in the tensile test and yet be entirely unsuitable to resist service where shock or alternating stresses are met. Another of the common tests is bending to a certain radius either hot or cold and it has been found that it is a very valuable test of certain qualities.

Chemical analysis is another powerful method of investigation and many specifications have been made in which its use is vital.

The microscope has been found to be of tremendous help in the study of metals and in fact it is now a necessary instrument in all laboratories. Its principal function is to determine the extent and location of impurities in a metal, to decide whether the structure is proper for the purpose desired and to decide whether various heat treatments will give satisfactory results. While no one method of test shows every thing desired to be known, the microscope is probably the most powerful single method of investigation in the case of metals, and in the study of welds it is particularly valuable because of the method of their formation. A weld is a casting and is subject to all the defects found in castings which are, however, exaggerated in the case of welds. It would be impossible in the time allowed to consider the defects in welds in all metals made by all welding processes and I therefore feel that it will be wise to confine my talk tonight to the welding of steel plate by the O. A. and metal electrode processes. Let us also consider that the welds we are to talk about are to be those in some important structure so that soundness and

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Paper presented before the September meeting of the **Chicago section of the American Welding Society.**

high quality are necessary. By soundness, I mean freedom from mechanical imperfections such as lack of fusion, the presence of films or other inclusions, gas pockets, slag, etc. It is not forgotten that welds of inferior quality may answer some purposes admirably and that if they do, there is no use in making better ones, but this is not the goal at which to aim for one who desires to make really good welds. The welding of steel is frequently considered as not being especially difficult and it is also sometimes considered that steel is steel and that no different treatment is required in the case of different qualities and varieties of steel. This idea is much less common today than it was several years ago, but it is still too prevalent for the good of the art. It is not as well known as it should be that a comparatively small difference in the percentage of carbon in the material being welded makes a very great difference in the results of either a bend or tensile test. If the carbon is .12 per cent or less, the material is soft, ductile and yields readily to any strain that may be put on it. Such material is frequently used for tanks and because of its ductility and comparative freedom from damage by heating, is admirably suited for welding. Structural steel, bar steel and boiler plate contain about .15 per cent to .25 per cent carbon and have a tensile strength of about 60,000 lbs., while the soft low carbon material has only about 52,000 to 55,000. Ship plate is required to have a T. S. of from 58,000 to 68,000 lbs. and in the heavier sections requires as high as .30 per cent carbon. It has been found by experience that the higher the carbon, the more difficult it is to get a satisfactory weld

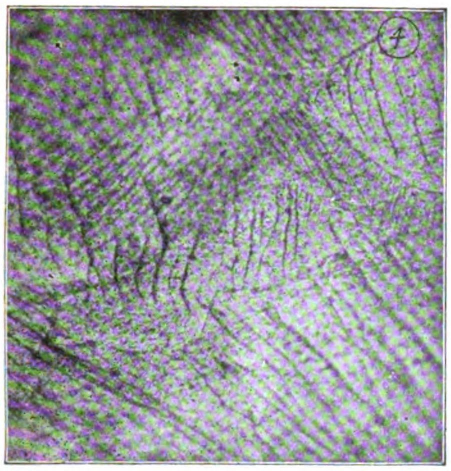


Fig 4—Armco iron strained. The curved lines are not cracks, but the edges of parts of the grains that have slipped past each other, so that the surface of each grain is stepped, as would be the top of a row of books that had slid past each other. In some grains there are two sets. They are called slip bands.

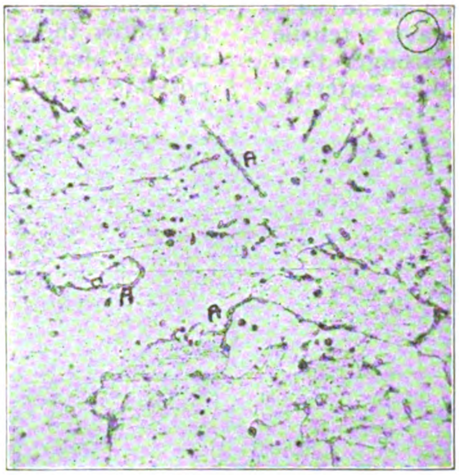


Fig. 5—A better oxy-acetylene weld than Fig. 6, but in the same material. Note the absence of iron nitride lines. The small dark dots are iron oxide, and they appear in all welds. The bands A at the grain boundaries are carbide of iron, or cementite, and contain all the carbon in the steel. There are more of them than in Fig. 6, showing more carbon present, and also that the metal was not as hot as in Fig. 6, because overheating burns out the carbon.

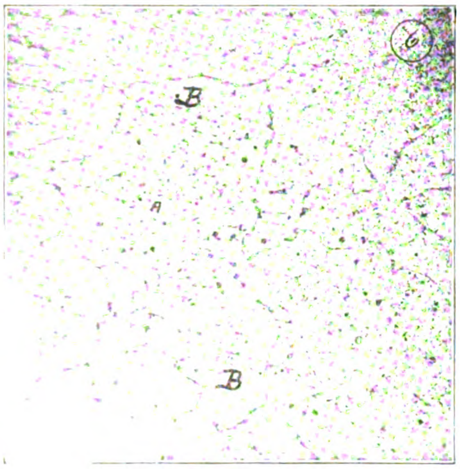


Fig. 6—A good looking oxy-acetylene weld, but made with too large a tip, as shown by the short straight lines in some of the grains, as above and below A, in the large grain B. These lines are iron nitride, and indicate absorption of both nitrogen and oxygen by the overheated metal. The grain boundaries are the irregular curved lines.

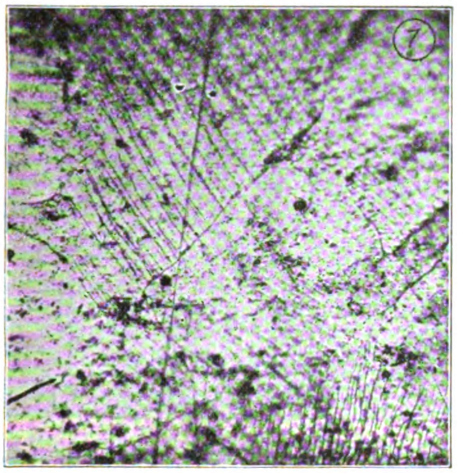


Fig. 7—Slip bands in good oxy-acetylene weld, stopping at grain boundaries.

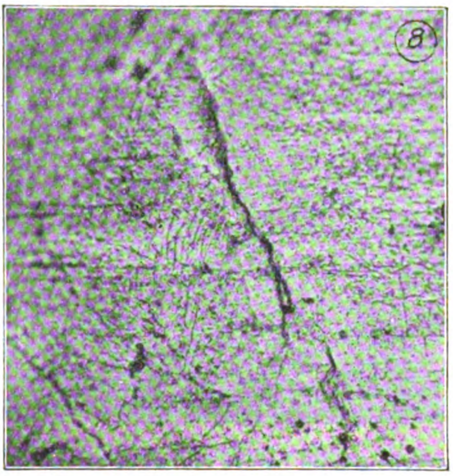


Fig. 8—Oxy-acetylene weld showing heavy slipping at grain boundary. This is not a crack, but shows a weakness there.

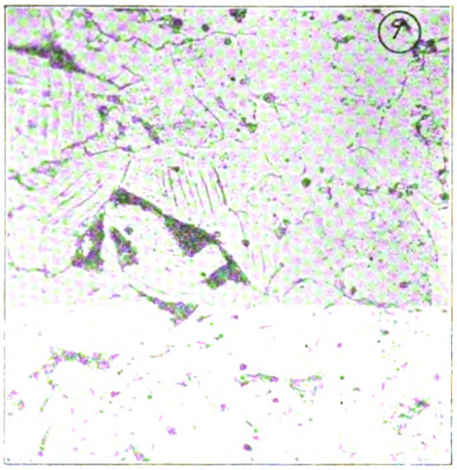


Fig. 9—Good oxy-acetylene weld made with rather high carbon steel, as shown by the pearlite grains A. Note presence of slip bands in all good welds, and their absence in bad ones.

and the more danger there is of injuring the metal being welded. From a metallurgical point of view this is entirely natural and to be expected. It is also evident that a weld made with a given welding rod or electrode can have only a given strength. If this strength is greater than that of the material being welded, the test piece will always break outside of the weld. If, on the other hand, the weld is weaker than the material being welded, the rupture will always take place in the weld. An O. A. weld made with ordinary low carbon welding wire will have a tensile strength of about 52,000 lbs. This is stronger than soft tank steel and weaker than the other materials mentioned. It is possible to get with alloy steel rods of proper composition a tensile strength in an O. A. weld of about 50,000 lbs. Neither of these materials will weld boiler steel, boiler plate or ship plate, so that the rupture will occur outside the weld when the section of the weld is the same as the section of the piece, so that in making tests of welded pieces, it is necessary to know accurately the character of the material being welded because if Welder Jones makes a weld in soft tank steel and Smith makes one in bar steel the first will break outside of the weld and the latter in the weld with a probable adverse criticism of Smith's work. The method of test to be applied in any given case depends largely on the use to which the welded piece is to be put. If it is to be used in a pressure vessel, I believe that not only should a tensile test be made but that an alternating stress test should be used because of the breathing of the tank due to changes of pressure. The latter test should also be applied where the weld is subjected to bending strain. There are no standards at present for weld tests but it is advisable, whenever possible, to follow those of the A. S. T. M. Inasmuch as a welded piece is not of uniform character, it is not possible to use the elongation and reduction of area as commonly measured. Where the break occurs in the weld, the elongation of the whole test piece tells very little about the quality of the weld and I have been in the habit of taking the elongation in each inch, two inches, etc., of the gauge length beginning at the center inch which includes the weld, and plotting these figures against the gauge length. Evidently, when the break is outside the weld, the various physical characteristics are those of the original material and not at all of the weld. The best test, in my opinion, to determine quickly the general character of a weld, is to grind it off level with the surface of the pieces

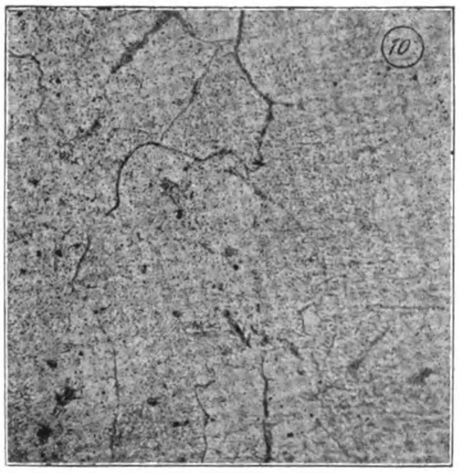


Fig. 10—Inter-granular cracks in strained oxy-acetylene weld.

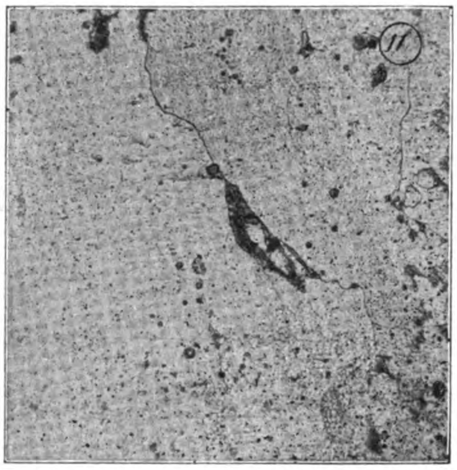


Fig. 11—Film of foreign matter, probably oxide, in oxy-acetylene weld.

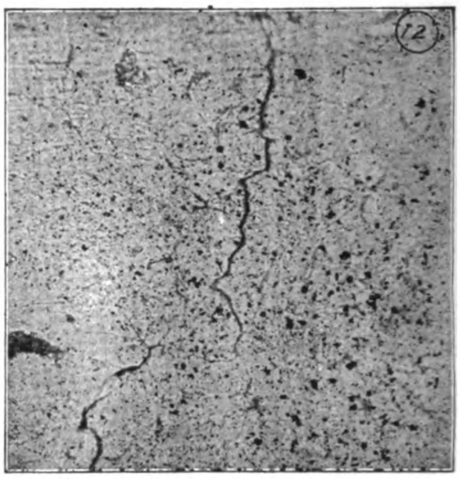
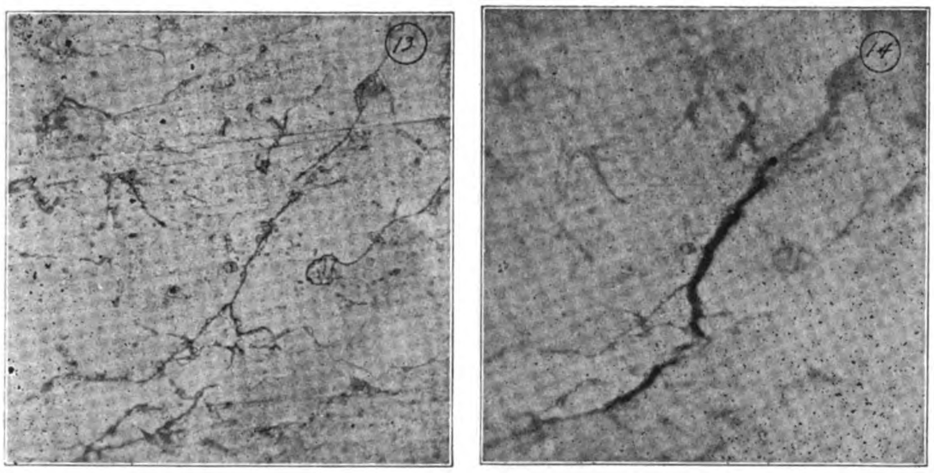


Fig. 12—Inter-granular cracks in strained oxy-acetylene weld. No defects visible before straining, showing that films were very thin.



Figs. 13 and 14—Visible defects in oxy-acetylene weld before and after straining.

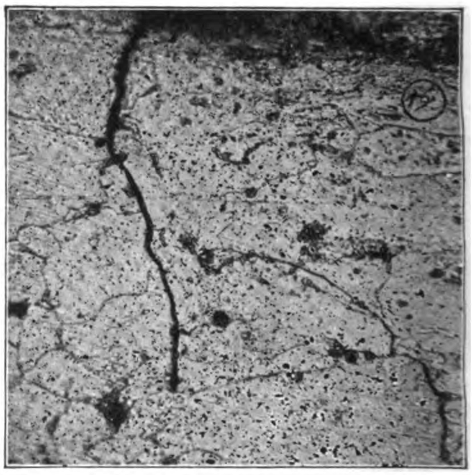


Fig. 15—Oxy-acetylene weld strained. Rupture is inter-granular.

and clamp it on an anvil, with the center of the weld level with the top of the anvil, the bottom of the V toward the anvil so that the top of the weld is stretched when the projecting end is struck with a sledge. The blow should not be too heavy and the number of blows and angle to which the piece bends before cracking are quite a good index of the value of the weld. It is true in this test, as in the tensile tests, that the quality of the material being welded has a great influence on the results. Stiff material throwing more of the strain into the weld while soft ductile material will itself take considerable of the bend. In the case of defective welds, that is, those not fused along the V or which contain slag or other inclusions, this test will at once develop the defects. If a welded piece were to be used in a place where it might become red hot such as, for instance, in a locomotive fire box crown sheet, it would be entirely proper to test the weld at a good red heat and I believe that it would be of much interest to all of you, if you would test some of your welds by clamping them in a heavy vise or on an anvil with the center of the weld about half an inch from the edge of the table or above the face of the anvil, heating them to a bright orange with the torch and then bending them as before with a sledge.

If such welds are made in half-inch by two-inch bar steel, a 90 degree single V being used, and they bend to a right angle cold without cracking on the outside, a welder may feel well satisfied with his work.

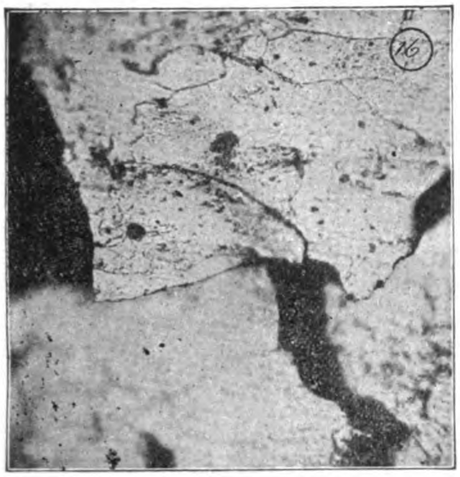


Fig. 16—Same weld as Fig. 15, but strained more. Note that upper part is lifted out of the lower.

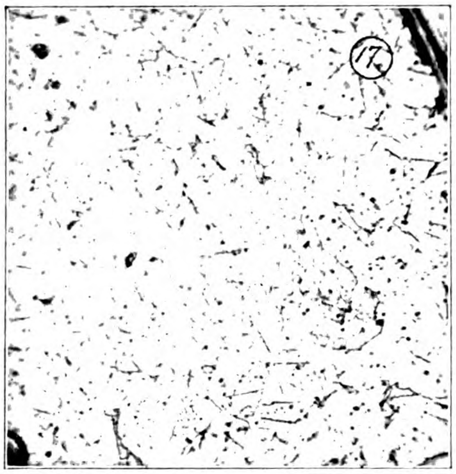


Fig. 17—Arc weld made probably with too long an arc, as there should not be so much iron nitride.

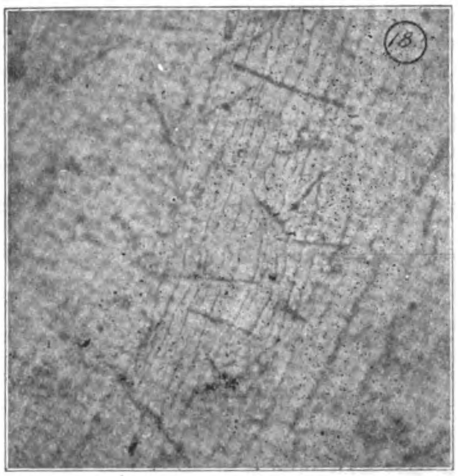


Fig. 18—Slip bands in arc weld. The heavier straight lines are iron nitride. These weaken the weld little, if any, because the slip bands usually stop at them, as at grain boundaries.

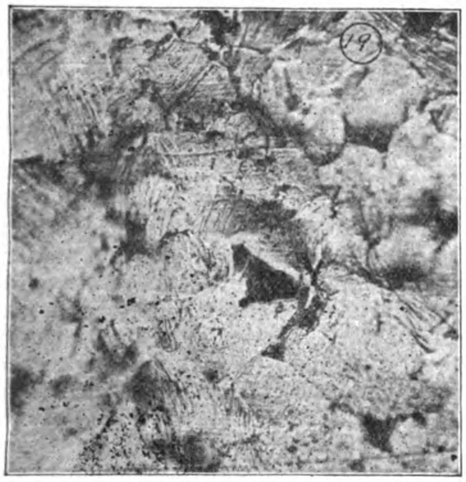


Fig. 19—Good part of arc weld heated red hot and slowly cooled. Distortion is by slipping as in normal steel. Large dark spot in center is iron nitride.

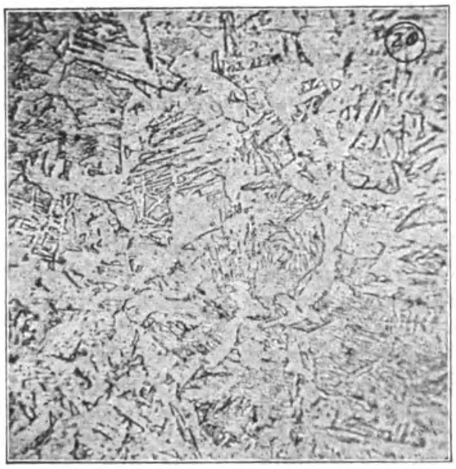
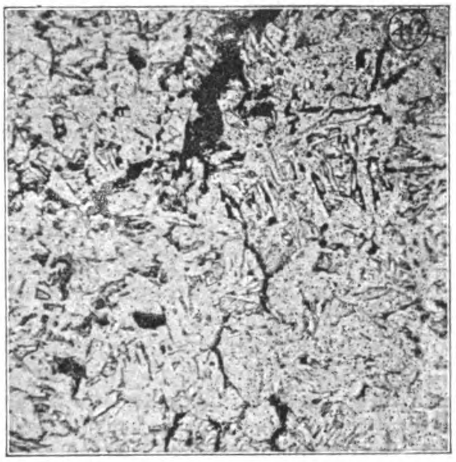


Fig. 20—Metallic arc weld heated red hot and quenched. No appearance of defects.



Fif. 21—Same weld as No. 20. There was no defect visible before strain. Ruptures are inter-granular.

It is not my intention to tell you how to make good welds, but it may be well to state that there seems to be quite a definite relation between the thickness of metal, the size of tip and the size of the welding wire, in the case of gas welding, and between the thickness of metal, the diameter of the electrode, and the current used, in electric welding. It is also to be understood that electric welds, except possibly those made with covered electrodes, will not stand as much bending as O. A. welds.

In many cases, the defects in welds are easily visible to the naked eye when tested. In other cases, they are not, and while it would seem plausible that the visible ones were more dangerous, yet to my mind, the hidden danger due to the ones that are hard to see is a matter that must not be overlooked. For many years, the dangerous defects in steel rails have been those which were not visible, and which have usually been very small at the start. During the war, when the demand for gun steel was very heavy, flaky steel, so called, was the material that gave the Government the greatest cause for concern. In fact, those who are best posted on the metallurgy of steel are paying more and more attention to the minor defects, which heretofore have been considered but of little importance. This is equally true in a case of welds and in finding out what a welder can do, this is one of the things that should be examined most carefully. There has recently been developed a method for testing rails for these hidden defects which has been devised by Mr. A. M. Waring. It consists of deeply etching a polished surface of the material under test. For instance, a section of a weld might be cut out with a hack saw, machined or filed to a true surface, and polished on various grades of emery paper, ending up with 00 Manning. It is then placed in a warm solution of 25 per cent hydrochloric acid and water for from half an hour to an hour. The acid will eat away the defects, making the edges of the material around them taper, so that rather large grooves and pits will be visible where the defects prior to the etching would be only microscopic. It is not necessary to warm the acid although it takes longer when it is cold. The bending test hot and cold, and the etching test, I consider to be of the greatest value in ordinary shop practice where it is desired to find out rapidly and quite accurately the quality of the work done.

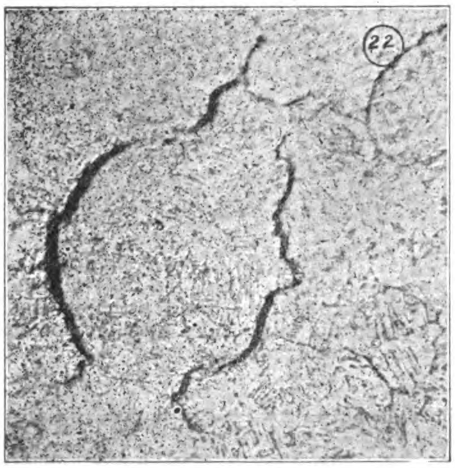


Fig. 22—Another view in weld No. 20. Ruptures are partly at a globule, the unbroken oxide film showing at the bottom, and partly where no defects showed.

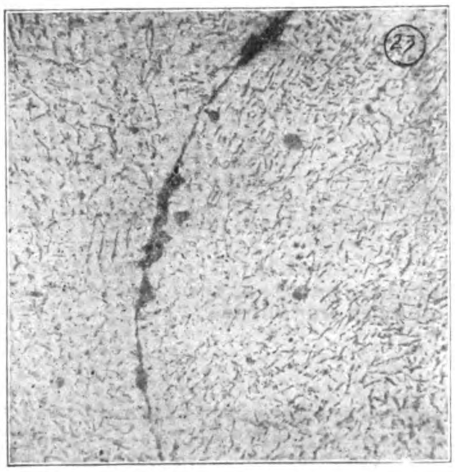


Fig. 23—Large defect in arc weld. Dark streak is oxide of iron.

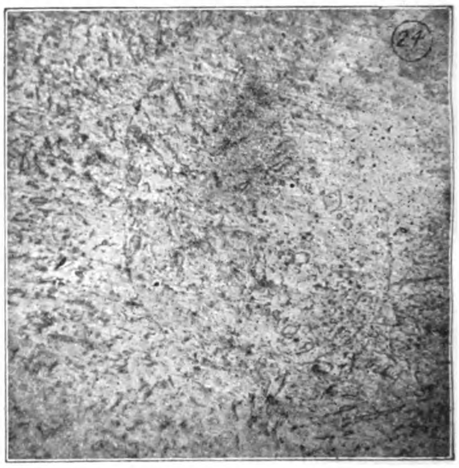


Fig. 24—Globule in arc weld about 1/300" diameter, surrounded by film of oxide about 1/800" thick. This is a weak spot in the weld, and such spots give first under strain.

Some of the defects in welds are visible under the microscope but others are not visible until the weld is strained. A small bending machine that can be placed on the microscope stage is very useful, because after etching the piece can be bent and examined and seen what the effect of the strain is. In the case of bare wire electric welds, the rupture, as far as my experience goes, always occurs at the grain boundaries even where no defects are visible there at the highest powers of the microscope. Of course, where there are visible defects, the rupture takes place first at these. Where there are not defects, the distortion occurs by slipping in the grains as in normal steel. The causes of these defects are to my mind almost always oxides of one or another constituent of the metal, but usually of iron. There is no positive proof of this as yet but there are indirect proofs. An electric weld that will bend very little may be made much more ductile by heating in a reducing atmosphere at a low red heat for one or two hours indicating that the weakness at the grain boundaries has been removed. The reducing atmosphere would seem to make it clear that the material at the grain boundaries was an oxide. Again, heating an electric weld in an oxidizing atmosphere makes it more brittle. The same treatment affects O. A. welds in the same way but in as much as they are normally not as brittle as electric welds, the improvement is not so noticeable.

These rough tests, while satisfactory for determining the general quality of the work, do not answer as a basis for design and more refined tests must be used as before referred to. I believe that the most important of these are the tensile and alternating stress tests. The tensile test can be made in any shop provided with the usual tensile testing machine. The alternating stress test is not as yet standardized even for unwelded material. I am inclined to believe that the machine devised by the Quasi-Arc Company is of considerable value although it does not give absolute results, that is, it does not give the amount of fibre stress to which the piece is subjected. During the war, the electric welding committee of the Emergency Fleet Corp. designed and built a machine for testing welds up to ¾-inch thick and 8-inch wide in which the fibre stress could be measured. The idea being to test large sections of welds. This machine has not yet been used. The ordinary machine for determining the resistance to alternating stress uses a rather small test piece about ⅜ by 2 inches in section which is vibrated back and forth about one-thousand alternations per minute. Another machine that will give considerable information is that designed by Mr. F. M. Farmer of the Electrical Testing Laboratories in New York. The test piece is round and is rotated under load. In both these latter cases, the fibre stress can be accurately determined, and this being known, the number of alternations or revolutions is the measure of the resistance of the piece. The difficulty with these two methods of tests is that the pieces are very small so that a small defect may cause the piece to break long before a larger piece would, or before a full sized weld would show any evidence of strain.

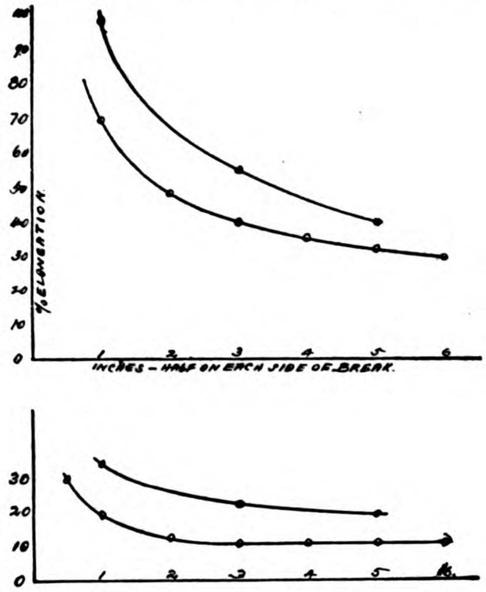


**Fig. 25**—The upper curves show the difference in elongation of two pieces of steel of the same tensile strength. The upper curve shows the more ductile piece. The lower curves show the elongation measured the same way, of welded test pieces of the same materials, the upper curve being in the more ductile material. So it is necessary to know all about the materials being welded before comparisons of welds can be fairly made.

A great deal may be learned from the appearance of a weld. It is difficult to describe the appearance of good welds but after they have been seen a number of times, an inspector can readily say whether the operator knows what he is doing. In gas welding, I would not accept a ripple weld in heavy material nor one which was narrower than about 2½ times the thickness of the sheet, because I have never seen a weld having these appearances that was properly welded. The appearance of properly made electric welds has been well described by M. Escholtz, of the Westinghouse Company, and has been published in several of the trade journals. The appearance in a gas weld of porosities in top, indicates that the metal has been overheated, and the same thing is true in an electric weld. Inasmuch as I believe that the serious defects in welds are caused by oxides, it would appear wise in the case of gas welding to use no larger tip than is necessary to produce thorough fusion. This means that the catalogue speeds of welding are impossible if good welds are desired. The same thing is true of electric welds. The reason is that at the high temperatures of the steel caused by too large a tip or too heavy a current, the metal becomes overheated, and in that condition combines more readily with the oxygen of the air or with any excess oxygen in the torch flame, and produces oxides which are readily dissolved by the melted metal. As the metal cools down, these oxides are rejected in large part and pass to the grain boundaries, as do other impurities, so that it is perfectly natural that material which has been seriously overheated should be more brittle and weaker than the material which has been properly melted. In conclusion, I have found in a number of cases that very great improvements in the quality of the work were made by using regularly the bending test above described and by carefully instructing the welders until they were able to make welds that would meet this test with unfailing regularity.

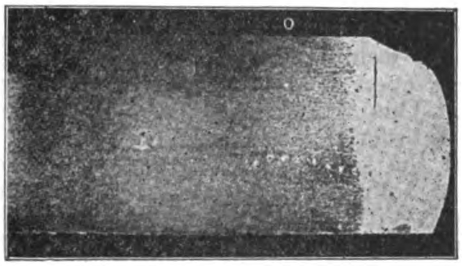


**Fig. 26A**—Oxy-acetylene weld in .50 C shell steel made with Roebling o-a wire.

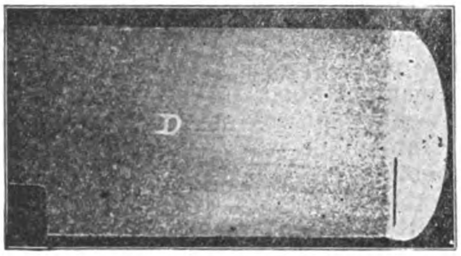


**Fig. 26B**—Oxy-acetylene weld in shell steel made with shell steel.

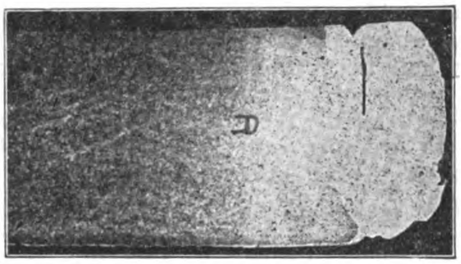


**Fig. 26C**—Arc weld in shell steel made with Roebling electric wire.

**Fig. 26, A, B, and C.**—In all cases the black line shows the original surface, and the white parts contain very little carbon. The heat effect extends to D in each case. The decarbonization of the original material and the change in structure, even if the weld were sound, would be a defect in some cases. Note that even where .50 C steel is used for welding, there is not much carbon left in the weld. Also that the loss of carbon is greater with arc welding than with oxy-acetylene.

## REPAIRING PROPELLER OF A DESTROYER.

An interesting repair was made on the starboard propeller of the destroyer Thornton, in the 1,000-foot dry dock at Balboa in May. The propeller had been damaged by touching one of the banks while in transit through the canal. The ends of the blades had been turned back through half of a circle. The blades were straightened and brought back to their original surface. Cracks were welded, the broken tips of two blades were repaired by burning (casting new metal into a mold at the end of the tips in such a manner that it fused with the old metal), and the propeller was balanced and replaced.

# The Art of Welding Gears and Pinions

### Advisability of Welding Each Tooth Separately or of Welding Several Teeth en Bloc—Selection of Proper Welding Tip and Filler Rod—The Writer Is a Practical Man.

By F. H. SWEET.

THE welding of gears and pinions with the oxy-acetylene flame is much the same as other automobile parts in relation to fusing of the metals and torch manipulation. In fact, the fundamentals of the torch-welding process are about the same on all classes of automobile work. But in welding most of the automobile gear wheels, a little more skill and deftness in the handling of the flame and filler are required. A little bit nicer touch is essential, so to speak.

The torch operator must place the filler metal just right and fuse it almost on the instant, if he would save himself a lot of time and trouble in finishing or machining the new teeth. On the other hand, he has the alternative of welding several teeth together, if he accidentally overmelts one or two. Perhaps it will be better here to refer principally to the repairing or building-up of worn teeth, since the welding of broken spokes, webs, hubs, etc., is not so difficult; it is more like the welding of other castings or forgings.

In the welding of gear teeth, there are several forms of damage to be considered. Generally speaking, these may be grouped into three classes: Where only the corners of teeth are broken or mashed; where the full length of the teeth is smashed; and where the entire teeth are torn out, or, in other words, where the teeth are broken off level with the rim.

The first group probably requires the finest skill, since the new metal must be added in very small quantities, a drop at a time, which is to be fused to the tooth without damaging the rest of it, and without permitting the new metal from spreading over a larger area than the damaged part of the tooth. Also, the new metal should conform as nearly as possible to the shape and size of the undamaged portion of the tooth, since it is sometimes a tedious job to file and fit a welded tooth, especially if the teeth are small.

A larger surplus of new metal may be added to the top of the teeth because it is readily ground off, but in between the teeth it should be fairly smooth.

The second group is the same as the first, except that the new metal is added in drops along the whole tooth. In this group, the welding is undoubtedly difficult because of the longer period of sustained effort required. The operator is liable to become nervous when concentrating his skill on the full length welding of a number of small gear teeth. Each drop of metal added to the edge of the worn teeth must be a continuation of the preceding drops—and each one must be thoroughly fused to the tooth.

The welder may use the alternative on the second group, if he chooses, and weld the teeth in a mass to be cut out afterwards. However, that is poor practice, unless only a few of the teeth are mashed. Even then, he should not employ this method unless his skill and experience are insufficient to permit him to build the teeth one at a time, for in both of the groups he may utilize the pressure of the flame to shape and smooth the teeth so they will need but little filing.

In the last group, however, it is probably more advisable to weld the teeth en bloc and cut them out afterwards, because, as a usual thing, where the entire tooth is broken out, only three or four teeth are gone. And where but a few teeth are broken out, the welder can save enough time on the welding to make up the time lost in cutting and filing; cheaper labor can be employed on this.

The missing teeth are welded in a mass thorogly fused to the adjoining good teeth on each side of the broken section. The melting and attaching of the teeth en bloc doesn't require the time or the skill, but the new metal must be solid and free from porosity, else the job will be done over again. Thus the welding of gear teeth en bloc requires nice judgment and fair knowledge of handling the molten metals in order to keep them clean. Hence, after all, it may not make much difference in what condition the job comes to the welder, he cannot slight the work and still make a weld.

There is much of the work of all three classes embodied in the last one, so let us take this for an example and try to make clear the different details of the process as applied to one particular job.

When welding the teeth en bloc, the first thing to do is to thoroughly clean the section where the teeth are missing. All grease and dirt are removed with waste and a wire hand brush until the surface is bright and bare. A handy way to do this cleaning is to play the welding flame over the surface until the grease is burned to a cinder, then scrape and brush this cinery stuff from the surface and from several teeth in the vicinity of the broken section.

This is a cleaning process which effectually prevents any foreign matter from melting and mixing with the weld, either in a solid or gaseous form, to cause porous or hard spots, some of which may not be discovered until the teeth are cut.

The next step in the process consists in arranging the gear for welding. This is handily done by suspending it upon a rod of iron placed across two V-blocks. This arrangement permits the gear to be revolved in order that the weld may be kept horizontal and at the same time it prevents the gear from slipping or rolling accidentally when the welder is not ready. With this device the weld may be made uninterrupted. However, it is not absolutely necessary to suspend the gear, since it may be welded upon a leveling plate just as well, the gear being rolled along the plate to keep the welds horizontal as the work proceeds. Either method simplifies the work as it permits the molten metal to be blown about without piling up on, or running off of the low spots. The welder can know where the metal will flow if the weld is level.

The next step in importance is the selection of the proper welding tip and filler rod. Both should be selected with care, for their choice can facilitate or hold back the progress of the welding. A tip too large will have too much power and will cause trouble in controlling the melted metal. It will melt too much metal too rapidly, thus clogging the weld and causing a poorly-connected fusion.

The flame of a large tip also makes the danger of burning the metal greater. The amount of filler metal is so small, in the first place, that to burn part of it is to burn practically all of it. This is augmented by the kind of metal used in most automobile gears. The different grades of steel of which the gears are made, burn or turn to oxide very easily. If a large welding flame is applied to a small bit of steel, it soon turns the steel to oxide; likewise, if a small flame is held too close or too long over one spot in a steel weld, the metal will be oxidized. On the other hand, a very small tip will not lend itself satisfactorily to welding automobile gears because it will not furnish enough heat to fuse the weld and at the same time supply enough heat to replace that which is lost through radiation and through conduction in the filler rod.

There should be enough heat in the flame to take care of these wastes and still keep the weld melting without burning. A deft manipulation will get both the weld and the filler melting in proper unity. A small flame can be used; so can one a little too large, but it is better to choose a size between the two. Then the weld can be melted ready to receive the filler when the filler is melted ready to be applied.

The manipulation of the flame is just as important as the choice of the tips. In fact, it is probably the most important parts of gear teeth welding—in other words, it can be used to make the weld a success or a failure.

Ordinarily the flame is never permitted to rest long over any part of the weld but is kept continually in motion, revolving in tiny circles over the weld and filler, or being used to paint or wash the molten metal into shape. In gear welding, or the welding of steel, the white cone of flame may be allowed to touch the metal, but should not be held so close that it spreads out or bends back. The tip of the flame is held close enough to barely lick the weld. This position is varied by raising or lowering the torch to conform to the needs of the weld, as to whether it is fast or slow enough. Sometimes the flame is pointed directly toward the weld.

At the first symptom of burning, the position or movement of the flame is altered. When the sparks commence to fly farther and faster, it is a sign that the torch manipulation should be changed, because the metal is starting to burn, or that more filler should be added.

Second only to the selection of the proper size flame and its correct handling, is the choice of the filler metal. A large size rod cannot be used successfully, since it requires a larger flame to melt it than is good for the weld. The larger flame endangers the weld from burning or supplies too much filler metal from the larger rod, thus tending to fill the weld with poorly-connected spots. A rod too small produces the opposite result.

There is no fixed rule for the choice of the filler rods and welding tips, due to the variation in some makes of torch, so the operator may have to depend somewhat upon experiment at the start. A filler rod about one-eighth of an inch in diameter should be right for gears of moderate size.

Some welders employ mild steel, or what is termed Norway iron, for welding gear teeth, but this is too soft to be entirely satisfactory unless the teeth are hardened after finishing. A good rod made expressly for gear welding, which may now be purchased from manufacturers, is a safer proposition.

The proper regulation of the flame is equally important with its manipulation, for an incorrect flame may nullify all other precautions. A flame that should be used on all gear welding is a strictly neutral, standard working flame—one composed of equal proportions of oxygen and acetylene. This flame should be obtained at the start of the welding, if possible, and maintained throughout the entire process.

If the oxygen is allowed to exceed the acetylene it will oxidize the weld, thereby causing porous, brittle metal. If the acetylene is allowed to exceed the oxygen, the metal in the weld and the filler rod will be carbonized and rendered hard and lifeless. In either event, the teeth will be poor when they are machined, probably too hard to file. Therefore, a properly manipulated flame should be a neutral one.

But to revert again to the en bloc process of welding gears: The neutral flame was held close to the cleaned section of the gear at the roots of one of the adjoining good teeth. Here the flame was revolved in circles about an inch in diameter, which were gradually decreased as the metal commenced to turn red, and as the heat increased, the flame was concentrated to a spot in the corner of the good tooth about half an inch across.

When this spot started to melt, the end of the filler rod was brought in contact with the flame. Then as the spot became fluid, a portion of the filler rod was melted into it, filling the corner perhaps a quarter of an inch deep. As this filling was being completed, the flame was gradually moved along the corner of the tooth and as gradually another portion of the rod was added to the melting weld. Then the flame and filler were again gradually moved to another portion of the corner. Thus a filet of new metal was fused along the full length of the base of the tooth.

The flame was then moved sidewise to add another layer back across the gear adjoining and melting into the first filet. This layer was made in a continuation of tiny pools, each of which overlapped and became a part of the others. At the end of this layer, the flame was doubled back to add another layer beside the second. Thus the entire section was filled, a strip at a time, until the whole surface of the broken part was filled with a layer of new metal about a quarter of an inch deep, carefully joined to the teeth of both sides.

During this proceeding the flame and filler were in continuous motion. The flame was played in tiny circles and arcs over the weld and the filler rod, the filler rod twisting and prodding lightly in the weld. At no time was it permitted to drip onto the weld, since this would tend to carry chilled or oxidized filler into the weld. The filler was kept feeding into the weld beneath the surface of the fluid weld.

Whenever dross or slag appeared that could be blown aside with the pressure of the welding flame, it was flicked out with the filler rod. The rod was also used to influence the flow and mixing of the metals, by twisting in that general direction.

No flux was employed on this job. In fact, none

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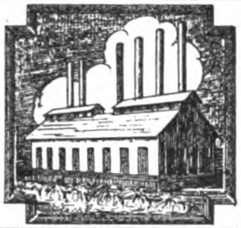
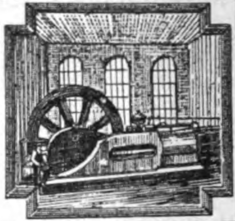


# STEAM POWER DEPARTMENT



# Modern Power Plant Management

## Description of the Various Methods Employed to Get the Proper Draft Regulation—High Efficiency in Use of Fuel Due to Proper Draft.

By ROBERT JUNE,
Mechanical Engineer.

THE attainment of high efficiency in the combustion of fuel is, to a large extent, dependent upon proper draft regulation. If there is no draft, combustion cannot take place. If there is insufficient draft, an immense amount of fuel is wasted and the boilers will not produce enough steam to meet plant requirements. If there is too much draft, you heat up all outdoors with the Btu's emitted from your stack. So you must have draft, and you want just the right amount.

The ideal draft is that which enables the boiler to carry the full load, while producing the highest practicable percentage of $CO^2$ and the lowest percentage of CO in the uptake gases. This ideal draft naturally varies with the individual plant, and with changing conditions in the boiler room. Among the factors which determine the amount of draft required, are kind and grade of fuel, design of furnaces and grates, and in particular the rating at which the boilers are driven. Thus, other things remaining constant, more draft is required to produce 20,000 pounds of steam an hour from a boiler than to produce 10,000 pounds.

A consideration of the fact just recited leads inevitably to the conclusion that every boiler should be equipped with a draft gauge. You must find out what the proper drafts are for different loads and other varying conditions on your boilers, and then see that exactly the required drafts are supplied. It is not our present purpose, however, to discuss draft gauges, but rather the means of supplying the pre-determined drafts.

Before starting our discussion, let us define the term "draft". Ordinarily this word is applied to two different conditions; first, the difference in head or pressure available for producing motion to gases; and second, the actual motion of gases themselves without regard to pressure. We will ignore this second meaning, and use the word "draft" as denoting the difference in density and pressure of the gases and air at various points.

### Natural Draft.

Forty years ago, nature alone was used for furnishing draft for furnaces. Since the weight of the column of hot gases in the chimney is less than the weight of an equal column of the cooler outside air, there is produced at the grate a difference in pressure which forces the hot gases up and out of the chimney.

With natural draft the chimney has to do three essential things:

1. Draw the air through the grates and fuel bed.
2. Draw the gases through the setting and tubes.
3. Draw the gases through the breeching to the stack.

With free-burning bituminous coal at moderate rates of combustion, the draft required for operations No. 2 and No. 3 may be approximately equivalent to the draft required for operation No. 1. However, if the coal is of poor grade, considerable more draft may be required for No. 1 than for Nos. 2 and 3. As a matter of fact, with fine anthracite, we may require five times as much draft for operation No. 1 as for the others. This means that our chimney must be designed to take care of operation No. 1, whereas, with the use of the mechanical draft, we can reduce considerably the functions of the chimney for this particular operation.

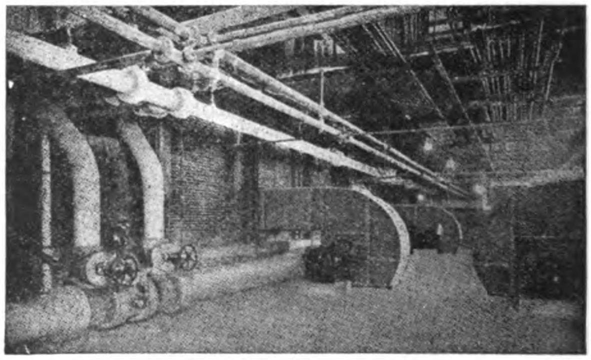


**Fig. 1—A fine example of forced draft installation.**

With natural draft, every time the fire door is opened, a blast of cold air is drawn in which scrubs the tubes and boiler shell, placing strains on the metal and furnace walls, decreasing the rate of heat absorption and cooling the fire. In addition, the gases are "short circuited," the strong suction pulling them through the boiler at high velocity, so that they take the shortest path to reach the stack and come in contact with only a portion of the tubes and shell, so that they leave the boiler with much of the heat in them which they would give up if made to pass through with lower velocity.

The draft produced by a stack depends mainly upon its height and the temperature of the uptake gases. Chimneys should always be designed to meet the maximum requirements, permitting the damper to be closed at times. There is usually no practicable means of increasing natural draft *per se* after the maximum has been reached. It must also be remembered that natural draft is particularly susceptible to atmospheric influence and may be seriously impaired by adverse winds.

### Mechanical Draft.

In view of the limitations of natural draft, it is not surprising to find that in many cases mechanical draft possesses very great advantages and under certain conditions, is indispensable. Mechanical draft is very flexible and readily adjusted to effect various rates of combustion.

Among the advantages of mechanical draft are:

1. It costs far less to install a compact and efficient mechanical draft system than it does to lay foundations and build a great chimney.
2. It makes possible any percentage of overload, thus going far beyond the limits of chimney draft. It is not at all unusual, with a properly designed mechanical draft equipment, to develop from 125 per cent to 225 per cent of the rated output of the boilers. If underfeed stokers are used, much higher overloads can be carried. The mechanical draft system of handling peak loads is usually found much more desirable than the method of installing sufficient rated boiler capacity to take care of the maximum peak loads, and it has found especial favor in those plants which are forced to take care of high peak loads during short periods of the year as well as those which run at continuous heavy overloads.
3. Inferior and cheap grades of coal which require a strong draft can be burned efficiently. Thus, the installation of mechanical draft at times makes possible the substitution of a cheap coal for a more expensive one.
4. It is independent of climatic conditions.
5. It assures individual draft control of each boiler, thus enabling operators to meet the requirements of complete combustion under existing conditions. This is very important. With natural draft the boiler nearest the stack usually receives more than its share of the draft and the boiler farthest from the stack gets much less than its share, hence rendering accurate individual draft control of the various boilers very difficult, if not impossible.
6. It enables operators to get up steam, or take on heavy overloads very quickly.
7. Short circuiting of gases is eliminated, as a boiler may be operated with a partially closed damper. This makes the entire surface of the boiler effective, increases, the production of steam, and prevents strains due to uneven temperatures.
8. Where with natural draft, manufacturing losses would result from the shutting down of one or more boilers, such losses can be eliminated by the use of mechanical draft which permits increasing the output of the remaining boilers.

### Types of Mechanical Draft Equipment.

Mechanical draft may be produced by any one of three distinct systems:

1. Vacuum or induced draft.
2. Forced draft.
3. Balanced draft.

With the first or induced draft systems, a partial vacuum is created above the fire, the effect being similar to, but more pronounced than natural draft.

Forced draft is produced by pressure developed in the ashpit, the effect being to force air through the fuel bed.

Balanced draft is a combination of forced and induced. Forced draft is used to drive the air through the fuel bed only. Beyond this point, induced draft is depended upon to create a suction throughout the furnace and setting. The adjustment, or balance, is such as to provide for practically atmospheric pressure in the combustion chambers—an extremely desirable condition.

### Induced Draft.

The earliest form of induced draft, consisted of the application of jets of live steam over the fuel bed or at the base of the stack. Tests have shown these jets to consume from 5 to 11 per cent of the total steam generated. They are extremely wasteful and should be tolerated only in plants where boilers need to be forced for very short and infrequent periods.

In the modern plant, induced draft is produced by means of a fan, the suction of which is connected with the uptake or breeching of the boiler, or batteries of boilers. The products of combustion are usually exhausted through a stub stack. In a typical installation, two fans of the duplex type are placed above the boiler setting. A by-pass is usually provided so that the fan cannot be cut off entirely in case of accident or when mechanical draft is not required.

Since the induced draft fan handles hot gases it must, under average conditions, have a capacity approximately double that of the forced-draft fan which delivers the cold air, but as the gases are of lower density the power required per cubic foot handled is less.

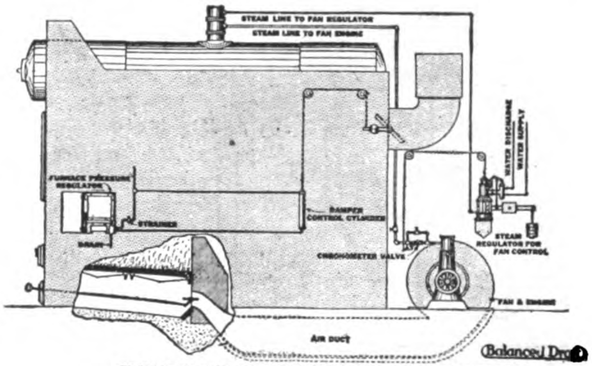


DIAGRAM OF BALANCED DRAFT SHOWING STEAM CONTROL OF FAN AND FURNACE PRESSURE CONTROLS OF FLUE DAMPER.

Fig. 2—Balanced draft installation.

The advantages of induced draft over forced draft are very pronounced. Among the advantages are:

1. With induced draft, fires will burn evenly all over the grates; there is no trouble from holes or patches burning in certain parts of the fuel bed as with forced draft, unless carefully watched.
2. It is never necessary to shut off the draft when firing as there is no pressure in the combustion chamber to force scorching gases and dust out of the firing doors when opened. The ashpit can be opened any time without shutting off the draft as at all points the flow is toward the place at which the greatest suction or depression in pressure prevails, this, of course, being within the induced draft fan.
3. The ventilation of the boiler room is better, as the aid drawn into the furnaces from the boiler room is replaced by fresh air from the outside, whereas with forced draft, there is a tendency for smoke and illsmelling gases to escape through crevices in the boiler setting and through leaks in the flues, especially when the path of the waste gases to the atmosphere is restricted by economizers.
4. The boiler flues can be kept cleaner as there is less lifting effect at the fire and consequently ashes and dirt are not carried in suspension and deposited in places where the velocity of the gases is lowered, to the same extent as is the case with forced draft.
5. With induced draft, very much larger fuel economizers can be used, as the temperature of the gases can be reduced to a very low point, enabling a large percentage of the heat leaving the boiler to be recovered without bad effects.

Induced draft can be used with all kinds of fuel and it is adapted to ordinary grates, rocking grate bars, chain grates, and other types of furnaces except those in which underfeed stokers and hollow blast grates are employed.

An induced draft plant costs considerably more than forced draft on account of the larger fan required, but the operating expenses are but little greater. With a boiler plant of 1,000 hp or more, the cost of a single induced draft fan, engine, stack, etc., will approximate from 40 to 50 per cent of the outlay required for a brick chimney of equivalent capacity, and the double-fan outfit will approximate from 50 to 60 per cent. The double-fan system is particularly adapted to plants which operate continuously and where even a temporary breakdown is a serious inconvenience.

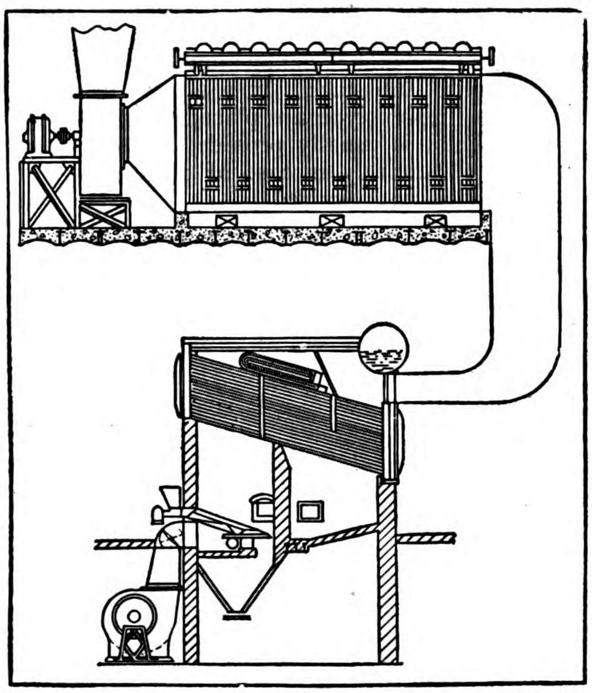


**Fig. 3—Arrangement of induced and forced draft fans with economizers and underfeed stoker.**

### Forced Draft.

Whenever the greater portion of the resistance offered to the flow of air is encountered in the furnace, it is advisable to use forced draft. Forced draft is created by the development of pressure in the ashpit through the agency of a fan or turbo-blower. The most approved method is to pass the air through the bridge-wall, thence toward the front of the grate, though it may enter through an underground duct or through the side of the setting. Forced draft is usually adopted in old plants where increased demands for power require that the boilers be forced far above their rating to save the heavy expense of new boilers, or in plants burning refuse, anthracite culm or screenings, which require an intense draft for efficient combustion. Forced draft is also well adapted for underfeed stokers of the retort type, hollow blast grates, and the closed fire-hole system. The air supply may be taken from the air chamber built around the breeching, thereby supplying the heated air to the fan and effecting a lower temperature in the breeching and a higher temperature in the furnace. The objection is sometimes raised against forced draft that the gases tend to pass outward through the fire doors when the fire is cleaned or replenished, since the pressure in the furnace is greater than atmospheric. This objection may usually be overcome by suitable dampers in the blast pipe which are closed on opening the fire doors or by having sufficient stack action to create a partial vacuum in the combustion chamber. With a boiler plant of 1000 hp or more, the cost of a forced-draft fan, engine, and stack, will approximate from 20 to 30 per cent of the outlay for an equivalent brick chimney. The power consumption will depend upon the character and efficiency of the motor or engine and will range from one to five per cent of the total capacity.

In recent years there has been a very marked increase in the use of turbo-undergrate draft blowers in place of the forced draft fan. Turbo-blowers are installed in each setting. They consist essentially of small impulse steam turbines directly connected to special designed propeller fans fixed in the side walls of the setting. The fan discharges below the grate and may be automatically controlled by damper regulation. The turbine exhaust may be discharged into the ashpit to prevent clinkers, or, it may be used in the feed-water.

Turbo-blowers are the least expensive of all kinds of mechanical draft to install and their ease of regulation is a point which commends them to the average plant engineer.

### Types of Fans.

Centrifugal fans used with either forced or induced draft may be divided into two general classes; those having rotors with a few straight or slightly curved blades of considerable length, commonly designated as steel-plate fans; and those having rotors with a number of short curved blades generally known as multi-vane fans. In general the multi-vane fan is more efficient than a steel-plate fan, as ordinarily constructed, and requires less space than the latter for equal capacity and efficiency. Another important advantage lies in the fact that the higher speed of the multi-vane fan permits of direct connection to high-speed prime movers. The steel-plate blower, however, is not necessarily a low efficiency device since by special design it may be made to give higher efficiencies than obtained from the curved short blade construction. Where first cost is a consideration, and where space limitation is of little consequence the steel-plate fan may be used to advantage. In small plants the power requirements for the mechanical

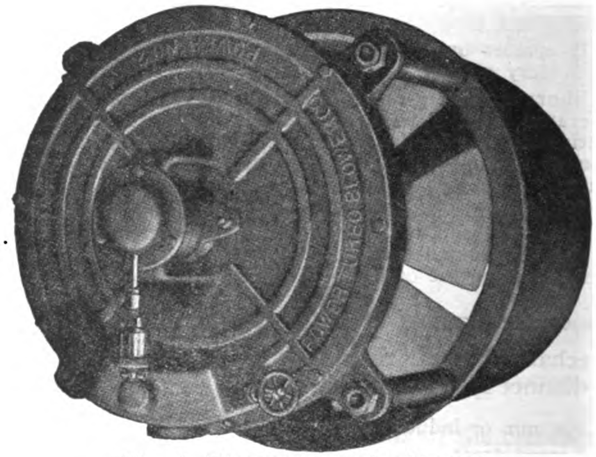


**Fig. 4—The power turbo-blower.**

draft system are low and the type of fan has but little effect on the overall cost of operation, but in large central stations the power requirements are considerable and the type and attending pressure characteristics greatly influence the ultimate economy.

**Balanced Draft.**

In the balanced draft system, a uniform pressure nearly atmospheric, is maintained in the furnace for all rates of combustion. In actual practice this ideal condition does not obtain, the pressure of the furnace gases being slightly below that of the atmosphere. To maintain atmospheric pressure in the furnace, natural draft can not be used, but instead a system of forced draft is utilized which gives a constant volume of air at variable pressure for a given speed of the blower, the pressure being controlled automatically according to the resistance of the fuel bed.

There are several ways in which this may be done. One method consists of a damper controller which automatically changes the position of the boiler damper in unison with the varying speed of the blower that supplies the air to the furnace, the speed of the blower in turn being varied by the steam pressure. Another method, and the more preferable is by using a furnace pressure regulator controlled by the pressure of the gases in the furnace chamber. When a change of gas pressure occurs, the damper regulator operates the flue damper in such a way that it counteracts the change in pressure, tending therefore to maintain a uniform pressure in the furnace chamber for all rates of combustion. In this way, the excess suction of the chimney beyond that required to remove the gases from the boiler is eliminated, and the chimney has but one function to perform, that of removing the gases of combustion from the boiler fires instead of having also to supply air to the furnace. As the entire supply of air is controlled by the power-driven blower, which is independent of atmospheric conditions, the fire temperatures may be controlled closely with great rapidity.

In analyzing the effect of balanced draft in raising the efficiency and capacity of boilers, it is necessary to consider the matter from several points of view. About 12 pounds of air are required per pound of carbon burned to complete combustion, and since any air in excess of this amount does not combine with the coal in combustion, but merely dilutes and cools the gases, it can be seen that only when the correct amount of air is obtained does the fire develop its maximum temperature.

As a boiler absorbs heat in proportion to the difference of temperature between furnace gases and itself the higher the temperature of the furnace gases above that of the boiler, the more rapid and greater, obviously, will be the absorption of heat by the latter.

It is not only in this way that the thermal efficiency of the fuel is raised, however. By eliminating all excess air the volume of gas for any definite weight of coal consumed is reduced to a minimum, and it follows, therefore, that the velocity of these gases in passing from the furnace through the boiler and into the chimney, is proportionately reduced. The time during which the gases are in contact with the boiler is an element which affects the heat transfer from gas to boiler, hence it naturally follows that the reduction in the velocity of these gases represents a direct gain in the heat absorbing capacity of the boilers, and is somewhat analagous to increasing the heating surfaces, but without increasing the radiation and construction losses incident thereto.

This comparatively slow movement of gas made possible by the balanced draft is giving most gratifying results by enabling increased evaporation per pound of coal, permitting in many instances, the use of a lower grade of coal than could be used otherwise, lower depreciation and lower maintenance charges, while the smaller coal consumption affects reduced labor costs.

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## SAVING FUEL BY CONTROLLING CHIMNEY LOSSES.

(Continued from page 677)

flue gas to carry away valuable heat energy as it passes up the chimney. Since the temperature of the products of combustion does not vary materially during short intervals of time, the percentage of $CO_2$ by itself becomes a most reliable index to the greatest loss of all—the sensible heat energy wasted up the chimney.

**Savings by Controlling Chimney Losses in a Small Plant.**

As a typical example of what can be done to save fuel by the simple regulations of the percentage of $CO_2$ it will undoubtedly prove of interest to compare the two $CO_2$ records as shown in Fig. 3. They were made at a small New England plant. A $CO_2$ recorder was connected with the boilers and placed in the office of the chief engineer without the knowledge of the firemen. They knew however that a twenty-four hour evaporation test was to be conducted and were instructed to utilize every effort to maintain the load during that period with the least possible amount of fuel. Although they worked hard to make a showing for themselves, the chart on the left illustrates that great variations occurred in the percentage of $CO_2$ and that the average was quite low. After the test had been completed, an auxiliary $CO_2$ indicator was placed at the boiler front for the firemen's particular benefit. They were advised that another test of the same duration would be run, but that this time only two things would be expected of them, viz, they were to maintain the steam at the required pressure and keep the $CO_2$ as high as possible. Not having heard of $CO_2$ before, the chief engineer simply pointed out the indicating column with a statement that it must be kept high and that the way to keep it high was to make the necessary adjustments of draft, thickness of firebed, etc. They were particularly instructed however to make only one change at a time in any adjustment, and then note the result; if the indicator went up they would know that the change was made in the right direction and if it went down they would know the change was made in the wrong direction. They were allowed to use their own ingenuity and to manipulate all furnace adjustments as they saw fit. They soon gained confidence and in a few days expressed their belief that the proper ratio of air to fuel burned could be maintained by watching the $CO_2$ indicator and making adjustments accordingly. The second evaporative test was thereupon started. The chart on the right hand side shows the results. This record is consistently higher than the first and the percentage of $CO_2$ is comparatively free from irregularities. The actual test showed a saving of 9.9 per cent made solely by the efforts of the firemen who had never heard of $CO_2$ before. Showings of this kind are being made repeatedly at hundreds of prominent and smaller plants throughout the country.

# Steel Plant Power Generation From Waste Heat and Coal

## A General Description of an Installation Where the Steam Derived From Waste Heat Was Supplemented by Coal Fired Boilers and Used for Electric Power Generation.

THE object of this paper is to present some of the practical problems encountered in the utilization of waste heat from open hearth furnaces for the generation of power for steel mill use. A description of an installation, wherein the steam derived from waste heat was supplemented by coal fired boilers and used for electric power generation, will also be included.

This installation was made in a steel plant where the conditions were not very favorable for the application of waste heat boilers, and should therefore show results which may be obtained in many plants similarly situated. This particular installation was made to obtain the following five results:

First—To utilize the waste heat of the open hearth furnaces.

Second—To assist in eliminating power shortage conditions which prevailed in the territory where this plant was located.

Third—To have standby electrical service when required.

Fourth—To be able to control peak loads occasioned by plant operation, and,

Fifth—To properly govern power factor conditions.

A few words will give some idea of plant arrangement at the point where waste heat was available. There was practically only one location for waste heat boilers without a considerable interference with existing steel plant operation. They were located at the base of the open hearth stacks, a trifle farther away from the furnaces than ideal conditions would dictate.

The source of waste heat was 10 75-ton open hearth furnaces fired with producer gas and occasionally tar. The furnaces were equipped with the ordinary regenerators and hydraulically operated reversing valves, the waste gases being conducted through an underground flue about 50 feet in length to the base of the stack. These stacks were 160 feet in height.

The furnaces each delivered at the boiler, an average of 65,000 pounds of waste gas per hour at a temperature ranging from 900 to 1,300 degrees F., depending upon the nature of the steel in the furnace, but averaging fairly well around 1,100 degrees during weekly operation when the open hearth is shut down over Sundays. Due to such shutdown, little steam is generated on Mondays and Tuesdays, the output increasing until the maximum is reached on Thursdays and Fridays.

Several types of boilers were considered: B. & W., Stirling, Bacon and Wickes vertical water tube. Any one of them could have been used with greater or lesser advantages and disadvantages, but the Wickes vertical two pass boiler was finally decided upon because the arrangement of this boiler permitted a shorter gas travel between the furnace and boiler in this particular location, the resistance of this type of steel jacketed boiler to air leaks, and gas explosions is very good and also because of the lower first cost. It was desirable to crowd the boilers into as small a space as possible, without sacrificing too much from an operating standpoint, in order to not interfere seriously with proper handling of the gas producers at this point. A total space width of about 16 feet was all there was to work in between the gas producer soot catchers and a depressed stock track.

The return of the gas to the base of the open hearth furnace stack after passing through the boiler and fan, was another factor in the location of the boilers, as it was desirable to keep a warm stack and allow its draft to assist the induced draft fans used in connection with the boiler. Each fan has a capacity of from 75,000 to 80,000 pounds of gas per hour operating at a speed of about 600 rpm producing draft of four inches of water, with a gas temperature of 450 degrees at the fan breeching. This gives a draft of about 1¼ inches at the furnace valve damper. The D. C. motors driving the fans are rated at 50 hp and are arranged with field control to give from normal speed of 585 rpm up to 10 per cent over normal, in order to adjust the draft on the furnace. Eight of the boiler fans are driven by motors and the remaining two are driven by 50-60 hp single stage steam turbines equipped with reduction gear. The exhaust of the turbines is used to heat boiler feed water. Practically the same range of speed is to be had as with the motors.

Verticle sliding waste gas valves were used at the boilers. These valves are two in number and counterbalance each other as shown, thus rendering their raising or lowering a comparatively easy matter for one man on the winch. A four-foot diameter saucer valve with vertical screw arrangement is also used to shut off the boiler gas passage at any time when the boiler is down and the furnace is discharging directly into the stack. This saucer is used only at rare intervals, when men are required to work on the boiler, or in the flue between the boiler and stack.

Superheaters were installed in the gas uptake to the boilers, at a point where the grates would ordinarily come in a coal fired boiler of this type. This was possible due to the relatively low temperature of the waste gas compared to the actual high temperature flame condition of a coal fired installation.

Standard soot blowing equipment was installed on each boiler consisting of five blower units for the boiler tubes and one unit for the superheater. Experience has since shown that two or possibly three units should be used on the superheaters to keep the corrugations clean.

Feed water regulators have been placed on all boilers and assist greatly in reducing attendance. They are not, however, infallible at all times.

These boilers have come well within the expectations, averaging 250 bhp each, during actual operating hours. A little trouble was experienced at first, with the vertical dampers, due to their sticking by reason of being placed out of line, and also by pieces of brick becoming displaced in the flue walls, but these were isolated cases, such as might be expected on any job. Then, also, a little trouble was caused by the strong fan draft drawing gas, on its way to the stack from the fan, back in over the tops of the dampers and recirculating it through the boiler. This was remedied by building a bulkhead wall between the valves, which effectually stopped the by-passing. It was also discovered by the operators, that considerable air was drawn in through the manhole covers of the damper chamber, down into the chamber and then into the boiler, necessitating a thorough packing of manhole lids with rope.

The first two boilers installed were of the B. & W. type and had auxiliary grates for coal firing in case of emergency. It is only necessary to resort to coal firing at the week end when too many open hearth furnaces are withdrawn from action at one time. The mill steam demand may then compel some coal firing for a few hours.

The second two boilers installed, as all of the remaining number, were Wickes. The first pair of Wickes were allowed to stand in the weather, but conditions became so bad, that a house was built over them and matters were greatly improved. All boilers are now housed in structural steel buildings with suitable doors and windows.

Another point which became very evident, was that the boiler fans should be of sturdy construction, with substantial bearings and shafts. The original fans gave a great deal of trouble, due either to too light pedestals, small shaft diameter, small bearings, or all three of these together. Especially in this location among the gas producers, where great quantities of fine ash sift in through every conceivable crack and opening, the bearing question seemed like a hard one to solve. Much heavier rigid bearings were finally adopted with substantial dust collars applied externally and clamped tightly so as to hold the felt rings snugly against the shaft. This has eliminated practically all of the ash menace, and has aided in avoided damage due to possible warping or bending of fan wheel by reason of heat, and by the accumulation of ash on the blading of the fan which would tend to produce an unbalancing. All fan bearings are water cooled, thus avoiding trouble which might be caused by reason of heat conduction along the shaft.

Gas explosions are experienced occasionally in the boilers, upon reversal of the furnaces, but this is very likely caused, in the light of experiments conducted, by the unconsumed air and gas which is discharged from the flues between the furnace reversing valves and the regenerators. A great many explosions can be avoided by the careful handling of the reversing valve by the furnace operator, but there are many times when they will occur in spite of his care. It is also quite possible that a careful timing of the throw over of gas and air valve with relation to each other would dispose of the difficulty; in other words allowing either the free air or the unburned gas to escape into the boiler first, by itself, and not in an explosive mixture of both together. The subject is worthy of considerable investigation.

The problem of location of turbine and condensing water cooling equipment, together with auxiliary coal fired boilers, was governed by several considerations. In the first place, the proper operation of such a power station in connection with the existing electrical equipment of the mill was of cardinal importance, in order to realize the greatest good from the enterprise. Then there was the question of available building space, both for the initial layout and also for future expansion. In addition to this it was highly desirable to keep as close to the source of waste heat steam supply as was feasible, without, however, losing sight of the item of proper coal handling facilities for the auxiliary boilers. And over and above it all was the eventual expansion of the steel plant which was to be reckoned with.

As a mater of fact, the switching facilities of most of the plant circuits were concentrated in the motor room or substation of the blooming mill. This together with sufficient space for the housing of the turbine, condenser, and switchboard equipment necessitated by the turbine, were largely the determining factors in the location of the power house. Practically the only undesirable features were the long run of steam line from the waste heat boilers, through the open hearth building, and the necessity for new coal handling equipment. The latter could have been avoided if the coal fired boilers had been placed at the gas producers along with the waste heat boilers. This was given careful consideration, but was finally rejected on account of the excessively crowded conditions which would have been brought about, and these boilers were located close to the turbine.

An additional reason for thus locating these boilers, was the economy of operation and minimum supervision required. It was at this location that the chief engineer of the station had his nominal headquarters, and could supervise these boilers much better, adjusting load conditions upon them at all times. It was quite evident that these coal fired boilers would have to bear the brunt of sudden loads and would have to drop off load just as quickly. Being under the eye of the chief or his first engineer, it facilitated matters a great deal. Then, too, there was ample space for future boilers.

The two boilers selected were Stirlings rated at 500 bhp each, and were set high as possible using building available, making the center line of mud drums 6'—6" from the floor. The boilers were equipped with Westinghouse underfeed stokers, six retort, and reciprocating stoker engine, 1,750 rpm blower fans for forced draft driven by 40 hp 2,300 volt 3 phase motors. Regular soot blower equipment was installed together with ordinary complement of draft gages, steam and water flowmeters, stack temperature thermometers and feed water regulators.

Coal is delivered outside the boiler house into a crusher pit from which an apron conveyor carries it into a storage pit inside the boiler house. An overhead traveling crane with clamshell bucket elevates the coal into overhead bunkers, from which it travels by gravity into the stokers' hoppers, through coal valves and piping.

The boilerhouse firing floor is elevated 10 feet above ground level, allowing sufficient space in the basement for fans, motors, steam piping, boiler feed pumps, and for miscellaneous boilerhouse storage. The ground level idea of the basement also renders an easy disposal of ashes, which at the present time, are wheeled out from the ash pit at the back of the boilers into the yard, without any uphill work for the barrow men.

It is worthy of mention that each boiler is equipped with an individual 100-foot stack, and either stoker fan is capable of furnishing sufficient air to drive both boilers at 200 per cent rating, which allows one fan to be down at any time for repairs, or necessary overhauling or attention. Likewise two boiler feed pumps are connected up, either one of which can handle the entire load at any time.

A feed water heater of ample capacity to take care of future increases, was set on the firing floor of the boiler house. This heater derives its steam from the boiler feed pumps, stoker engines and also from the exhaust of the high speed turbine driving the condenser pumps of the main turbine. This last is a variable factor, as the turbine exhaust is also fed into a bleeder stage of the main turbine.

The general operation of this boilerhouse has been very satisfactory, with the probable exception of smoking of boilers under high ratings. This trouble was disposed of by removing some of the baffling of the last pass, which gave somewhat increased stack gas temperatures but was ultimately of an overall benefit.

The general arrangement of the steam piping for the entire proposition, although apparently somewhat drawn out, as in fact it is, the results obtained since operating have been very good. The waste heat boilers feed directly into a common main line which is located under the open hearth charging floor. This line is provided with five loop expansion bends, as the total length of the run is 730 feet and there were space limitations. At each expansion bend there is a sufficiently large drip pocket and trap to take care of any excess of water which might occur upon warming up sections of the line or otherwise. From this main waste heat line, which is composed of four, five and six inch pipe, a tie line of eight inch pipe connects with the main steam header at the power house. This is the line which runs through the open hearth department in the basement between two furnaces, and then passes through a tunnel which is continuous from the pouring pits to the power station basement. This eight inch line, as well as the main power station header is placed five feet below ground level, thus locating it well out of harm's way. Necessary expansion bends and drip pockets are provided in these lines.

At the coal fired boiler house, the eight inch line joins with the header from the coal fired boilers and forms a 14-inch main. A compound bend is provided at the main turbine to relieve the steam chest of all strain due to expansion and contraction of the steam main. Adjustable spring supports working in a vertical plane maintain this header in alignment very satisfactorily.

The valves in this steam system were installed with a view to operating demands and safety. All boilers are equipped with non-return valves in addition to necessary gate valves. The waste heat boilers have triple acting valves, but the coal fired boilers were fitted with single acting non-returns. The supply of waste heat steam enters the main header at power house through a single acting non-return valve which was installed as a safety measure in case of a break in the extensive steam system required by the waste heat boilers, and also on account of the inaccessibility of those lines.

The steam temperatures have worked out satisfactorily, giving a supply of superheated steam to the turbine. The drop in the run from the waste heat boilers is approximately 125 to 150 degrees F., when the steam flow is small. With about 30,000 pounds of steam per hour passing through this line the temperature drop does not exceed 100 degrees. The initial temperature secured at the waste heat boilers range from 500 to 600 degrees F. All of this steam piping is covered with two inches of asbestos felt, protected by a waterproof covering.

The normal pressure of the steam system is 200 pounds per square inch and the coal fired boilers are equipped with superheaters designed to deliver 100 degrees superheat.

The turbine equipment consists of semi-double flow Parsons type steam and designed to operate on 180 pounds steam at 3,600 rpm. This drives a 6,250 kva 11,000 volt three phase 60 cycle generator. A low level jet type condenser serves the turbine, and this is driven by a 300 hp single stage turbine through a reduction gear. The condenser circulating pump delivers the water directly into the cooling tower.

The generator is equipped with self contained fans, circulating air for cooling, which is drawn into the turbine through an airwashing equipment located in the basement. The turbine is set at an elevation of seven feet above the power house floor level, where the switchboards and auxiliary equipment are located. The elevation of the turbine was necessary to secure enough head room for installation of condensing equipment, but also allows the turbine operator a good view of switchboard and the balance of the substation.

A cooling tower is located about 200 feet from the turbine which has a capacity of 7,000 gallons of water per minute. This tower covers an area 35 feet by 110 feet and is equipped with four pairs of 12-foot diameter fans, which are driven by a 40 hp motor on each pair. These four motors are each connected to the fan shaft through a silent chain drive, and operate the fans at about 160 rpm. Each motor and drive is installed in a separate house and arranged so that any pair of fans can be operated as required. The selection of a cooling tower was necessitated by space limitations, and also in order to eliminate trouble which might be caused by spray from a pond interfering with railroad shifting around the plant.

The actual results obtained from a month's run on the waste heat boiler equipment show that with an average of 6.8 boilers in continuous operation, that 15 per cent of the steam produced is required by feed pumps and fans, 45 per cent is usued by gas producers and other mill operations, leaving 40 per cent available for power production by the turbine. During this same month, 90 per cent of the steam produced by coal fired boilers was delivered to the turbine, and this steam, combined with that delivered by the waste heat boilers, generated 1,200,000 kwh. The coal consumption amounted to 1¾ pounds per kwh.

This month's run was made during the summertime when the best vacuum was not obtainable, and also when load conditions were not of the best to secure good results, on account of reduced mill operations. It is apparent, that with more waste heat boilers in service, different results can be secured. In this connection, it is estimated that with an average of eight waste heat boilers in continuous service, the

## THE ART OF WELDING GEARS AND PINIONS.

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is required on steel welding because the melting point of the oxide is below that of the metal and, therefore, the oxide either consumes itself or melts and floats to the surface, where it may be blown or scraped aside.

After placing the first layer in the broken section, the flame was applied to the first filet again where another one was melted along the corner formed by the good tooth and the first filet. Care was taken to see that the second filet actually joined the one beneath it and the side of the tooth. This second filet was added in small connecting portions along the tooth, from end to end. The process was then repeated back across the gear on top of the first filling, making certain that each pool of metal fused with the lower ones and the surrounding ones. At times the flame was dropped to an angle to blow the edges of the pools together smoothly. Thus the first series of pools was covered by a second layer, from end to end of the section, and the whole section was filled level with the top of each tooth on the sides of it.

A slight surplus of filler metal was added above the tooth level for machining purposes; also the filled part was filled to give it the proper crown or curve to preserve the outer diameter of the gear. Then the gear was removed from the V-blocks and placed flat upon the table where one side of the weld was gone over.

The flame was played around over the sides of the weld, or more properly, perhaps, over the end of the new tooth section. The hollow or weak spots were remelted and filled while the higher or rough spots were leveled. These irregularities were doctored with the flame pressure and the filler rod. The gear was then turned over to bring the opposite side of the weld upward, which was also remelted and cleaned the same as the first side. Particular attention was paid to the corners to be sure the ends of the new tooth would be sharp and metallic. Then the gear was ready for machining.

If the welder shop is equipped with emery grinders or other machines for cutting out the new teeth, this part of the repair is quite simple. However, many welders do not possess these facilities, therefore the new tooth will have to be worked out by hand. This seems to be a very slow, tedious process, but in realty it is not half bad if the mechanic goes at it in the proper spirit. Of course, he must be very careful toward the end of the process to prevent making the teeth too small. If he calipers frequently and works carefully at the last, he can produce an almost perfect tooth.

In this particular case, the welded gear was taken first to an ordinary emery wheel, where the face of the weld was ground almost level with the old teeth both on the edge of the gear and on each side. This saved a lot of hard filing. Next the gear was fastened in a vise with the welded section upward. Then a fine-tooth hacksaw was used to cut the sides of the teeth.

In this process a slight surplus of metal was allowed on each side of each tooth to provide stock metal in filing to accurate size. The sawing was done straight down to the rim of the gear, leaving the pitch for the finer work of filing. Before sawing, however, careful measurements were made to locate each tooth accurately. Center punch-marks were made to prevent mistakes. After sawing between the teeth, the next step was the cutting out of the sawed portions. This was done with a sharp chisel having a narrow blade. The metal between each pair of teeth, or more strictly speaking, between each pair of saw cuts, was removed, a thin layer at a time almost to the bottom of the teeth. These sections were cut out, one after the other, leaving a thin surplus at the bottom to be filed out more accurately. It was a rather slow process, and the chisel was sharpened frequently to prevent mishaps. One little false blow might have ruined the whole job. When all the chiseling was finished, the teeth were filed to correct size with a fine flat file, the last layer of each filling being done very slowly and carefully. Then the tops and ends of the teeth were filled flush with the old teeth, and the gear was ready for use.

## STEEL PLANT POWER GENERATION FROM WASTE HEAT.

(Continued from page 692)

same amount of coal was burned in the month's operation referred to above, would have produced, at least 1,400,000 kwh, resulting in a coal consumption of 1½ pounds per kwh.

This power plant is operated in parallel with 7,000 kva turbine power installation, located at a blast furnace about three-quarters of a mile distant, and also with a commercial power company. Experience with attempting to operate in connection with the power company's system indicates that this introduces a source of trouble due to failure of their supply, on account of power shortages, line troubles and lightning disturbances. Also the power company objects to the low power factor of the load that is given their system.

## DISCUSSION ECONOMIC CONSIDERATION OF POWER PLANTS.

(Continued from page 670)

power. But in the light of the writer's experience this is not the case.

Lastly there is another type of low level jet condenser not considered by Mr. Keating, which has recently been installed in a number of larger plants. The writer refers to low level multi-jet condensers which are generally familiar in small sizes. It has not been generally known, however, that they are built for large capacities. The principal of operation of this type of condenser is shown by the attached drawing. It requires neither a removal pump to withdraw the water from the vacuum chamber, nor a separate vacuum pump, the only auxiliary to the condenser being the injection water pump. Although this condenser requires more water than other types of low level jets, the power required is usually less. It is this combination of simplicity and reliability with ease of installation, moderate first cost and power consumption which largely accounts for the number of installations that have been made recently. It is impossible to give an analysis of the cost for the multi-jet condenser for comparison with the types considered in Mr. Keating's paper for the installations under discussion, because it would involve assumption of cost of other parts of the plant, including construction work, the bases for which are not given in detail in this paper.

# INDUSTRIAL RELATIONS

## CHECK OF IMMIGRATION REQUIRES LABOR CONSERVATION.

FRANCES A. KELLOR,

Vice Chairman, The Inter-Racial Council.

The time has passed when the American employer could count upon an unlimited supply of labor from abroad. Emigration from the countries of Europe will be strictly regulated by the governments in the near future, and is already being directed in some of the Old World nations, which have begun to realize the value of their workers.

This is the case in Italy, for instance, which has supplied us with such vast numbers of unskilled and semi-skilled laborers. The French government has offered Italy six tons of coal per month for each Italian miner induced to go to France, and the Commissioner of Emigration of Italy is advising his people to emigrate to France. It is asserted that opportunities are better there than in America, both for steady work and high wages.

Other countries are making efforts to keep their citizens at home. Greece is offering inducements of farms to the people, having passed an act by which large land owners may retain only one-third of their estates, while surrendering two-thirds to the peasants. If this offer should not be sufficiently persuasive, emigration from Greece may be prohibited at any time by law. Conditions in that country are being studied at present to determine what action may be necessary to prevent an undue exodus of the population. The extension of Greek territory is a powerful reason for keeping these people in their own country.

Similar conditions are found in Finland, where areas have been set aside for settlement, and farm implements and supplies are offered to small cultivators on liberal terms.

These instances show the attitude of foreign governments toward their nationals. Instead of permitting their men and women to leave at will and select their own destinations, as in our port, emigration will be curtailed by many governments to the extent deemed expedient for their own interests. Instead of the emigrant selecting his own future home, the governments will advise him where to go, and in some cases will retain him as a citizen, with voting rights, even while living abroad. At present the Lithuanians in America have three deputies to represent them at the next meeting of the Constituent Assembly of Lithuania, while Italy has under consideration a plan to give its nationals throughout the world elective representation in its government.

This means that the immigrants who do come here will have less tendency to make America their permanent home and become citizens, hence we will have to make greater efforts to assimilate them than we have done in the past. It indicates a policy opposed to the best interests of America, and which should be opposed by our people before it becomes an accomplished fact.

Some of the foreign nations are planning to do the things which America should have done long ago; to protect immigrants from fraud, to establish official information bureaus, to take care of their savings through branch banks and generally to look after their welfare.

International agreements are being made between Old World countries regarding immigration. Diplomats of Hungary, Poland, Greece, Italy, France, Lithuania, Spain, Portugal and the Balkan countries have taken the lead in such conferences, but the United States, which has so much at stake in the matter has shown indifference. If our supply of coal, iron, oil or cotton were threatened, the whole nation would be aroused, but with the imminent curtailment of our labor supply, even at this time of acute labor shortage, the government and the business men who should be interested are remaining quite apathetic.

The new era of world-wide business requires an international view of conditions if American interests are to be adequately cared for. To help meet this need, the Inter-Racial Council has planned a series of bulletins reflecting the world movements and endeavoring to interpret them.

These are no longer mere academic questions, but matters of direct concern in the American business man. When the manifesto of a leader in Russia can react with greater force upon the workers than the words of the plant executives, or when a stream of literature in foreign languages can counteract utterances in the American press or in plant organs, it is essential to the self-interest of the American business man that he should know about these things and act with information on the facts.

Meanwhile it is to the interest of every industry to conserve the present inadequate labor supply and make the best use of it. The tendency of the foreign-born workers to return to their old homes could be checked by every legitimate means. The most powerful inducement to them to remain is of course just and humane treatment, with no discrimination in wages, housing, living and working conditions between them and the native born. Efforts should be made to establish closer relations with the foreign-born workers. If they have legitimate causes for discontent, the grievances should be understood and removed. The same spirit of coöperation that is being secured through enlightened employers and their English-speaking workers should be developed into relation to the foreign-born laborers.

This is not "coddling," not philanthropy, but labor conservation. As, in the early days of America, we were wasteful of our resources, coal and oil, natural gas and timber, until we saw the results of extravagance so at present we are as wasteful of our manpower, as if the supply were inexhaustible.

We should not be deceived by the temporary increase in immigration. The figures that indicate a large number of arrivals at Ellis Island fail to show the fact that the proportion of women, children, professional and clerical workers is so great as to afford little relief to our labor shortage. Of the manual laborers coming in, a large percentage are men who went abroad to fight and are now returning to their old jobs. Of new workers, to do the essential work of America, there is an exceedingly small percentage, while recent correspondence from all parts of the United States indicates serious shortage of labor in almost every section.

The course of action for the employer is therefore, first, to conserve labor as carefully as he conserves his raw material; second, to regard immigration problems with the same interest that he gives to international commerce, realizing that America is no longer isolated and that what happens in the Old World today, will be reflected in his own business tomorrow.

An international conference on immigration is planned for 1921, in which the United States should play a leading part. Business men who are interested may obtain further details through the Inter-Racial Council, Woolworth Building, New York.

# FOREIGN RELATIONS

## CANADA'S PIG-IRON PRODUCTION FOR HALF YEAR.

(Monetary Times (Toronto), August, 1920)

The total production of pig iron in Canada during the first half of 1920, according to statistics collected by the mines branch of the Department of Mines, Ottawa, was 502,667, short tons (499,891 tons made in blast furnaces and 2,796 tons made in electric furnaces), as compared with a production of 524,977 tons during the first half of 1919 and 392,804 tons during the second half of 1919. The average monthly production of pig iron during the first half of 1920 was 83,778 tons, as compared with an average monthly production of 87,496 tons during the first half of 1919, 65,467 tons during the second half of 1919, and 76,482 tons for the whole year. Canada's monthly production of pig iron, in short tons, since 1916 has been as follows:

| Month | Tons 1916 | Tons 1917 | Tons 1918 | Tons 1919 | Tons *1920 |
|---|---|---|---|---|---|
| January | ........ | 89,187 | 74,239 | 103,963 | 81,494 |
| February | ........ | 83.801 | 78,507 | 86,840 | 70,864 |
| March | ........ | 103,789 | 96,848 | 91,286 | 77,155 |
| April | ........ | 100,564 | 104,331 | 93,359 | 86,303 |
| May | ........ | 109.891 | 104,867 | 83,059 | 97,593 |
| June | ........ | 99.998 | 103,037 | 66.470 | 89,258 |
| July | 92,012 | 93,499 | 109,723 | 60,927 | ....... |
| August | 87.864 | 100,727 | 96,164 | 67,404 | ....... |
| September | 102,744 | 100,690 | 95,102 | 56,806 | ....... |
| October | 113,608 | 103,277 | 106,962 | 56,049 | ....... |
| November | 104,436 | 97,905 | 106,585 | 73,092 | ....... |
| December | 106,496 | 87,152 | 119,186 | 78,526 | ....... |
| Total | †1,169,257 | 1,170,480 | 1,195,551 | 917,781 | ‡502,667 |
| Monthly ave. | 97,438 | 97,540 | 99,629 | 76,482 | 83,778 |

*Subject to revision. †Total for year. ‡Six months.

The blast furnace plants active during the first half of the year were those of the Dominion Iron & Steel Co., at Sydney, Nova Scotia; the Nova Scotia Steel & Coal Co., at North Sydney, Nova Scotia; the Algoma Steel Corporation, at Sault Ste. Marie, Ontario; the Canadian Furnace Company, at Port Colborne, Ontario; and the Steel Company of Canada, at Hamilton, Ontario. The blast furnaces at Midland, Parry Sound, and Deseronto, Ontario, were idle throughout the period. Pig iron was made from scrap iron and steel in two plants, the Shawinigan Foundries, Shawinigan Falls, Quebec, and the Hull Iron & Steel Foundries, Hull, Quebec.

## GERMAN SCRAP IRON PRICES DURING 1920.

Consul Frederick Simpich, with the American Commission at Berlin, reports under date of July 16 that the Frankfurter Zeitung has published a table comparing the prices of scrap iron as they were quoted in the course of the first six months of the year 1920. The prices are reprinted below. The figures represent marks per ton. New York exchange for the mark is about $0.025; September 1, 1919, 300 marks; January 1, 1920, 1,350; February 1, 2,000; March 1, 2,100; April 1, 1,500; May 1, 1050; June 1 725; July 1, 600.

## IRON AND STEEL WORKERS' WAGES IN NORWAY.

The first decision of the Norwegian Court of Compulsory Arbitration was recently rendered, according to a report from Minister Schmedeman at Christiania. The matter before the court concerned the iron and steel workers, and the following decisions were handed down:

The minimum wage for skilled iron and metal workers shall be 1.50 crowns per hour. Ordinary workers shall receive a minimum wage of 1.30 crowns per hour. In addition to this minimum wage, every man worker above the age of 19, except apprentices, will receive a personal increase of 40 öre per hour, while the wage for women over 18 years of age was made 1 crown per hour and for women under 18 years 85 öre per hour. Women will, in addition, receive a personal increase of 30 öre per hour. Apprentices will receive 65 öre per hour, the same as previously, but in the tenth half year will receive 1.30 crowns, as compared with 1.10 crowns under the old tariff. For those workers who are sent occasionally to perform work at distant places an increase of 15 per cent was granted. The wages of joiners, painters, and woodworkers were likewise increased proportionately, so that the average increase for the workers is from 20 to 25 per cent.

[There are 100 öre to the crown, and the normal value of the crown is $0.268 United States currency.]

## BELGIUM ORDERS GERMAN FREIGHT CARS.

(Consul General Henry H. Morgan, Brussels, July, 1920.)

Belgium has placed its first order for material in Germany since the armistice. It is destined for the State railways, but was ordered by the Ministère de Ravitaillement; this is explained by the fact that at the time of the liquidation of the Comté National de Secours et d'Alimentation, which looked after the provisioning of Belgium, there remained a large stock of food supplies for which a buyer was sought. Germany offered to buy it, and thus became indebted to Belgium for about 60,000,000 francs. It offered to pay the debt in merchandise and proposed machines and other things. The railroad department then intervened and suggested to the service of Ravitaillement that an order for material be placed up to the amount of the debt. It was proposed to buy 3,000 freight cars at 20,500 francs each, but German manufacturers demanded 21,000 francs per car. The railroad department declined the conditions. The Ministère de Ravitaillement, however, accepted, and it was understood that the difference of 500 francs would be charged to the Ministère.

Negotiations are under way with German manufacturers for the supply of 2,000 to 3,000 additional freight cars, which are to be furnished along with the others at the end of next March.

Belgian manufacturers demanded 27,000 francs a car, which might still be increased in case of a further augmentation of wages; and this price did not include wheels. Nevertheless, the railroad administration, desirous of satisfying the national industry, proposes to order 3,000 to 4,000 cars in case its conditions are not too rigid.

A Dortmund firm has already furnished Belgium with 300 freight cars at about 16,000 francs each.

Reconstruction of more light railways in Belgium is announced by La Société Nationale des Chemins de Fer Vicinaux.

# PRODUCTION TOPICS

## MEANS TO INSURE BETTER BELT SERVICE AND LONGER BELT LIFE.

By F. D. Rich.

Human nature plays an important part in getting service and longer life out of a belt. It is human nature to do things in what seems the "easiest way", not always realizing it is often the most expensive and usually the most laborious, because it necessitates doing the work over and over again. This applies particularly in the case of cutting belting and joining it.

Cutting the ends of a belt to put it into service seems such a simple thing that often the belt man does not give it the consideration necessary to insure the best results, and much of the difficulty with otherwise good belts is due to their not being cut and joined accurately. When you know how, it is as easy to make a belt joint which will run the same as endless, as it is to do it by careless rule-of-thumb methods.

When a belt runs "wobbly" or races back and forth across the pulleys, it is not giving its best service nor can it have its longest life. If you have a belt that is repeatedly jumping off the pulleys, you are paying about twice as much as you should for it, because its life is being shortened and you are paying for power that is lost and production that you don't get. You are also repeatedly paying for unnecessary time and labor in fixing things up.

Provided that its ends are cut square and it is joined with care, a belt can be made to run as straight as an arrow if the pulleys are lined up true.

Don't guess at cutting your belt ends. Use a square—always—and use it with care. If you do not use a square, one or both of the ends will be cut unevenly or irregularly, which prevents smooth running. Even the use of straight edge does not assure the perfect results obtained by using a square, for the slip of a fraction of an inch will bring the belt ends together at an angle.

This results in the belt "shimmying" on the pulleys, which is bad for the belt and impairs its service, for as it moves from side to side, the line of direct pull, "A-B," moves from one side of the belt to the other, imposing shifting and irregular strains, which no belt can stand indefinitely.

There is only one way to assure correct results. That is to use a belt square and to keep it in place until you have cut all the way through the belt. Don't just scratch the surface and then hack through. Cutting to the square assures an even cut all the way through the belt and all the way across. It means that the belt ends can be brought together in a tight butt, evenly-running, flush joint.

For belts up to 15 or 18 inches wide you can use the ordinary square. Press it firmly against the edge of the belt, and, when cutting, hold the knife vertically.

Be sure your knife is sharp. Wet the point of your knife occasionally, as it cuts more easily when the blade is wet.

When a number of belts have to be cut, a good stunt is to drive two nails in a large block of wood, and against these set the edge of the belt and the edge of the equare. This prevents either the belt or the square slipping. Some men tack a slip of leather or a piece of old belt on the end of the block to protect the point of the knife as it comes through the belt.

Wide belts are more difficult to square correctly, and the difficulty is often increased by slight variations in width, which throws the square out. To avoid this and assure perfect results, the method described below has proven the best.

At any point near where you are going to cut the belt, measure across and find the center. At any distance back of this, two or three feet, find the center again. Between these two center points draw a clean, sharp line. This marks the center axis of the belt.

Now, using the square against the center line, trim off the end of the belt, holding the square firmly in position while you cut all the way through. Too small nails driven in on the center line will keep the square from slipping.

You can determine exactly where you want to cut after the clamps have been put on and the belt brought into position. Then measure forward from the line "D-E" an equal distance on each side of the belt to the cutting point. You can use calipers and measure over the belt clamp or run your ruler through the edges of the clamp. As a matter of convenience, always cut one end of the belt square and get it ready for making the joint before putting the belt into the clamp.

Remember that when you are doing a job, it is much easier to do it right than to do it over. This applies to making the completed joint as well as to cutting the belt. Therefore, it is best when joining a belt to do so in a way which is permanent and which insures the belt's most satisfactory service.

Personally, the writer, who has had considerable experience in working with belting manufacturers in solving the difficult problems of efficient belt joining, is very much opposed to methods which punch holes in the belt or which in any way cut or weaken the lengthwise, power-carrying fibers of the belt.

Any thinking man can see that no belt can give better service than its method of joining will permit and if wasteful or destructive means are employed, the strength of the belt is lessened, its service impaired and its life shortened.

It is no uncommon thing to see, in journeys through manufacturing plants, laced belts in which from 40 per cent to frequently more than 70 per cent of the cross section of the belt is removed in punched holes. How in the name of common sense can such a belt joint be expected to give the full service of the belt? Many manufacturers are today running belts much heavier and more expensive than their requirements, in an attempt to get strength at the joint.

There are many types of metal fasteners in common use which from an engineering standpoint are but slightly, if any more satisfactory than lacing methods for several reasons. First, because many of them sever the lengthwise, power-carrying fibers. Second, because others place all the strain in a straight line comparatively close to the end of the belt. Third, because some make a joint which is so stiff and hard that they pound on the pulleys and cause the belt to break back of the joint. Fourth, because many put metal in contact with the pulleys, which causes noise and wears and crystallizes the metal, so that such joints must be constantly watched, both to prevent danger to workmen and failure of the joint.

# WITH THE EQUIPMENT MANUFACTURERS

The Electric Arc Cutting and Welding Company has developed a welding machine weighing complete 100 pounds, which, with reasonable care, will accomplish any work in or around a garage or garage machine shop, etc., that is, the machine will use electrodes from 1/16" to 5/32", and will operate continuously with the medium and small sizes, and intermittently on the large size. Their standard lines of machine are built to operate absolutely continuously, but they have by careful design and development produced this machine which will fill any and all requirements for automobile work, plumbing shops, sheet metal work, electrical shops, etc.

It is also very handy in a job welding shop where electrical experience is available and discretion is used as to its capacity.

This is the 23 Jewel thin model Swiss movement of the welding industry. The very best materials are used and every available dodge is taken to reduce the weight and maintain its capacity. It probably has not as many limitations as one would be led to believe from the foregoing. The only point is that it cannot be guaranteed on a heavy boiler or engine job for continuous duty, although it will do such work if used with discretion, and with the proper discretion, the machine will last a life time.

This machine will operate on either 110 or 220 volts, and any frequency specified in the order, and can be made for other voltages, but their standard worked up design is for both of the voltages mentioned, that is, there are two coils in series on 220 volts and in multiple on 110 volts. The power supply must be of at least five kva in order to use this machine, and be within the underwriters' regulation. While it will operate from a lamp socket with the smaller electrode, it is not allowable or good engineering to do so. If five kva is available, however, it will operate connected to the panel board from which the lights are distributed. It will operate for less than one kwh per hour or in general, less than three cents an hour. It will use any type of electrode made, but quoting from the electrodes that they sell, the cost per hour for absolutely continuous use, would be from 10 to 20 cents, depending on the type and size used. Maintenance charges there are absolutely none as there is not a moving part to the machine. The case is sealed and if anything goes wrong, they would prefer you to return it unopened.

The connections are very simple. Two wires are hooked from the machine to power supply and two other wires which are furnished with the machine, are attached to a plugging in board unit mounted on this machine for regulation. In order to make the machine standard, each machine is provisioned for operating on the following voltages, 90 to 130 volts and 180 to 260 volts.

The uses to which this machine may be put cover every field of arc welding that could be encountered, except perhaps doing very heavy work rapidly, as above stated; however, it will do the heavy work but at a reduced rate, i. e., not economical for production but at a rate perfectly economical for emergency repairs.

Around a garage or automobile repair or machine shop where most of these machines are installed, the uses to which this machine can be put are as follows: Repairing of seared cylinders by spotting and peening with a nickel electrode, and straight repair welding of cracked and broken blocks, mudguards, and mudguard brackets, cracked water jackets on cylinders, broken frames and other chassis parts, such as lamp brackets, bumper brackets, tire holders, step braces and any part around the chassis which has become loosened due to wrenching or wear, may be tightened forever with this machine. Squeaks and rattles otherwise impossible to get rid of, can be cured forever and very quickly with this machine. In the automobile machine shop, parts that would have to be bushed or replaced can be built up to beyond their original dimensions and machined down to their correct size. Other broken parts such as crank shafts, connecting rods, universals, worn teeth either gears or connection dogs, or anything worn in or about the car, can be built up and machined back to its original dimensions.

Lead burning, either on or off, can be done beautifully with this machine. That is, batteries can be taken apart, repaired and put together again without flame or fire, the attachment for this purpose being simply a white hot glowing point made so from the characteristics of the machine. Spot, butt or tack welding of small thin pieces can be rapidly accomplished with this machine. The machine, because of its portability, can be taken anywhere to accomplish the job such as the repair of a heating or power boiler, or tightening of radiator sections in places where it would not be advisable to dismantle and where the machine can be easily moved.

Places other than garages where this machine would be ideal are as follows: Electrical shops, plumbing shops, building contractor, maintenance of tanks and boilers, sheet metal and tinsmith shops, blacksmith shops, factories of any nature employing machinery where emergency repairs would keep production at its height. This machine can be used for thawing out frozen house water pipes also.

An instruction book covering completely the art of arc welding as is developed today, accompanies each machine.

## THE ALLEN-BRADLEY CLAPPER-TYPE CONTROLLER.

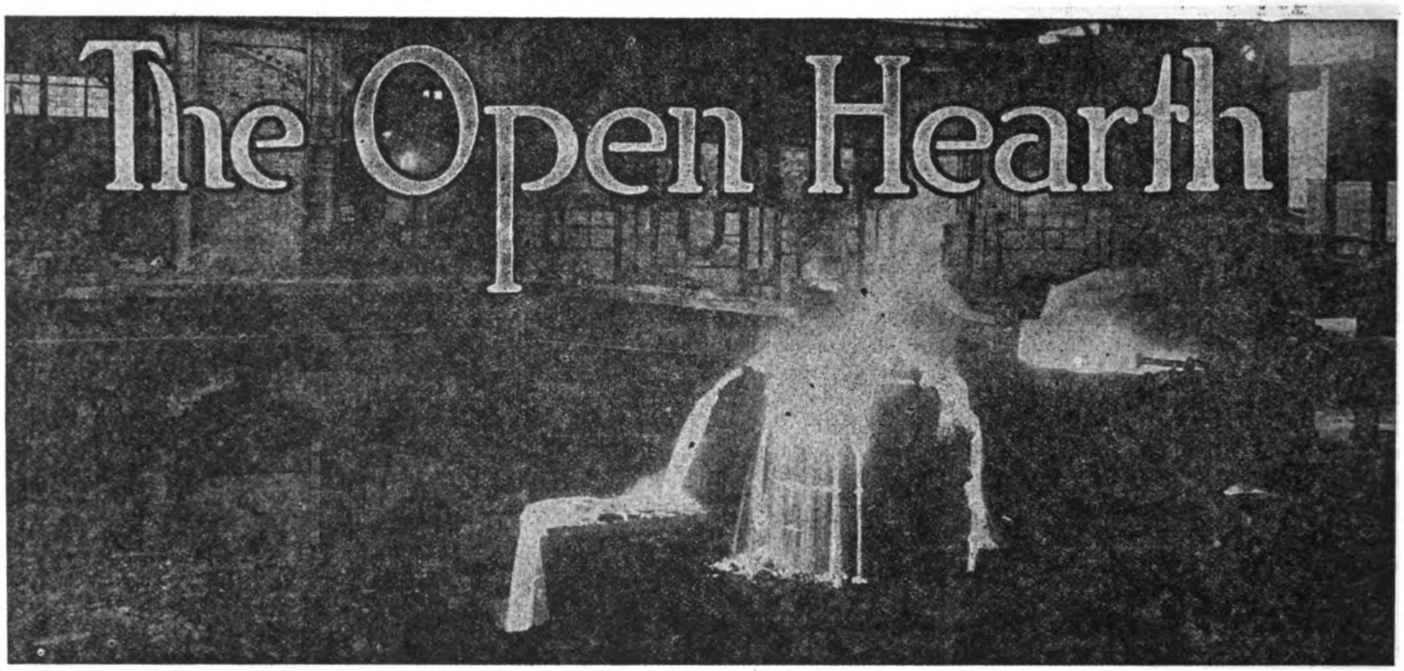
The Allen-Bradley Company, of Milwaukee, Wisconsin have developed a new line of mill, crane, and hoist controllers to supplant their well-known Types Q, R, and S controllers for the same service. The new controller, made in sizes ranging from one hp to 150 hp, is known as the "clapper type controller", primarily because all switching and contact-making is done with a clapper-switch contactor.

The controller is further simplified by the use of the Allen-Bradley graphite compression resistor, mounted within the controller, avoiding the use of grids or wire-wound resistors and the need of step contacts. All speed control is obtained by pressure variation upon the resistor column applied by the control lever.

The salient features of the new line of controllers, for either direct current or alternating current, may be summed up as follows:

Clapper contactors of copper-to-copper, rolling type are used exclusively.

Clapper switches, mounted inside the controller, are mechanically operated, and perform all switching up to 100 hp. Larger controllers use external magnetic clapper switches actuated from a pilot switch within the controller.



# The Open Hearth

Robert McClurkin, formerly superintendent of blast furnaces at the Northwestern Iron Company, Mayville, Wis., and later connected with the Thomas Furnace Company, Milwaukee, Wis., has been appointed assistant superintendent of the Illinois Steel Company blast furnaces, at Gary, Ind., succeeding J. T. Mauthe, resigned.

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F. B. Hufnagle. for the past eight years general superintendent of the Alliquippa plant of the Jones & Laughlin Steel Co., has resigned to accept a position as president of the Pittsburgh Crucible Steel Company. Mr. Hufnagle will accept his new position immediately.

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Charles Davis has been appointed superintendent of the sheet mill department of the Youngstown Sheet & Tube Co., Youngstown, O. Mr. Davis succeeds J. J. Beck, who recently resigned. Guy Ohl has been appointed assistant superintendent succeeding Mr. Davis.

* * *

Robert B. Hitchcock has resigned his position as chief chemist at the coke plant of the Youngstown Sheet & Tube Co., Youngstown, O., to accept a similar position with the Woodward Iron & Steel Co., Woodward, Ala.

* * *

Frank C. Davies, formerly foreman at the coke plant of the Youngstown Sheet & Tube Co., has accepted the position of assistant superintendent of blast furnaces of the Donner Steel Company, Buffalo, N. Y.

* * *

Leslie Bradford, superintendent of the open hearth department of the Broken Hill Proprietary Company, New Castle, Australia, is in the country seeking equipment for an electric furnace plant he is to establish at Sydney, Australia, for the manufacture of steel castings and alloy steels. His investigations have taken him through Continental Europe and Great Britain.

* * *

The Pulaski Iron Company, announced the appointment of Richard Peters, Jr., as manager of sales. He was formerly with Rogers, Brown & Co., and Robert C. Lea & Co., Philadelphia. They will hereafter sell their foundry pig iron direct to consumers instead of through brokers, as has been done in the past. The company will soon expand its sales department to cover the territory formerly handled by agents.

W. C. Sutherland, formerly in charge of the Allenport, Pa., plant of the Pittsburgh Steel Products Company, has been promoted to the position of general superintendent of both plants of the Pittsburgh Steel Products Company. Mr. Sutherland succeeds Mr. Wikstrom who will visit Europe to study methods used there in making seamless tubes.

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J. E. Tintsman, formerly superintendent of the Scottdale, Pa., plant of the United States Cast Iron Pipe & Foundry Co., Scottdale, Pa., has been named to succeed P. T. Laws, who has been promoted to be assistant general manager of the company. Charles Seitz, formerly in charge of the mechanical department has been appointed superintendent to succeed Mr. Tintsman.

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John T. Higgins has resigned his position as night superintendent at the Hazelton mills of the Sharon Steel Hoop Company, Sharon, Pa., to accept a similar position at the Western Reserve sheet mill plant at Warren of the Brier Hill Steel Company, Youngstown, O.

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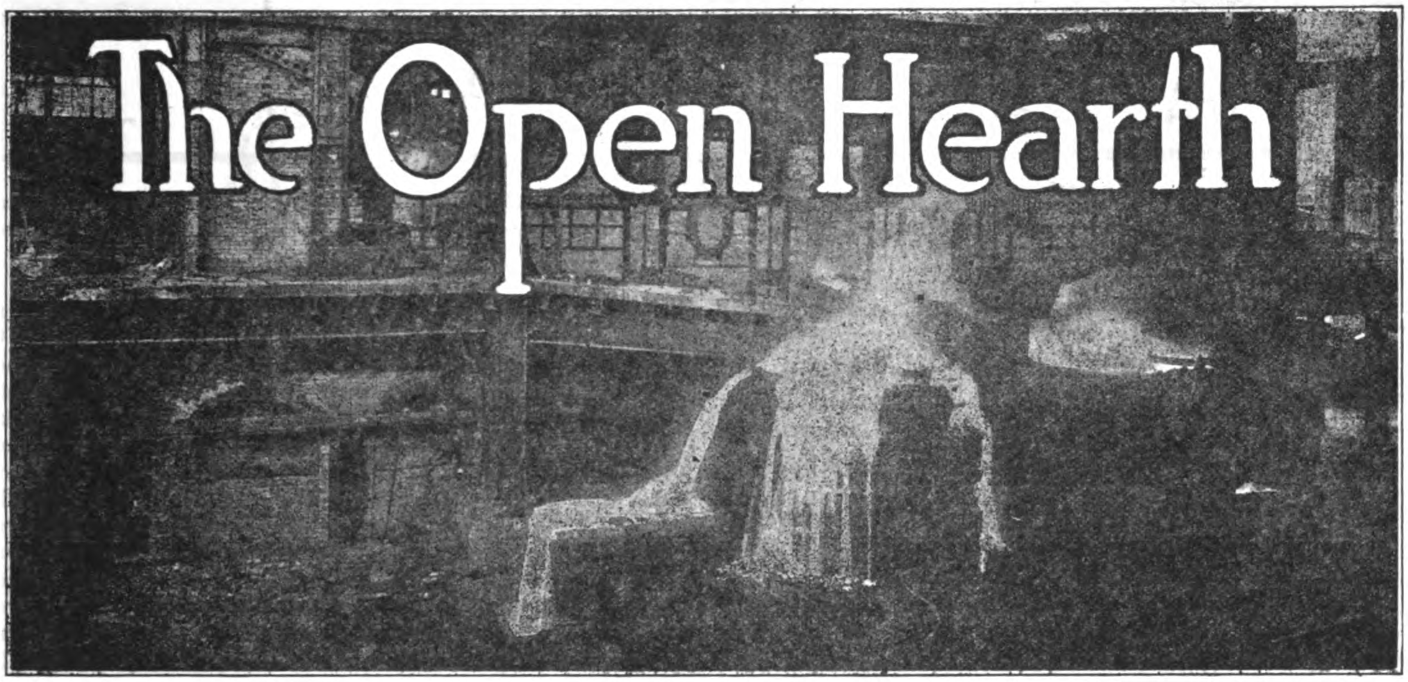
Robert G. Ashman has resigned his position as manager of the steel department of the Worcester Pressed Steel Company, to become the general manager of the J. D. Crosby Company, Pawtucket, R. I., manufacturer of cold rolled strip steel and flat wire. Mr. Crosby, who had contemplated retiring from business activities for some time, will remain as president and in an advisory capacity.

* * *

John W. Dougherty has resigned as vice president of the Crucible Steel Company of America and as president of the Pittsburgh Crucible Steel Company, and has been elected president of Marquette Iron Company, New York. Mr. Dougherty has recently acquired a substantial interest in the latter company. Following his graduation as mining and metallurgical engineer from Lehigh University, he was connected for 22 years with the Pennsylvania Steel Company, becoming general superintendent of the steel works. When he gave up this position in 1911 the plant consisted of five blast furnaces, 19 open hearts, three Bessemer converters, rolling mills and by-product coke ovens, employing 9,000 men. He resigned to join the Pittsburgh Crucible Steel Company. At that time the Midland plant had a capacity of 350 tons daily from one blast furnace. He increased it to two blast furnaces of 1,150 tons capacity, 12 90-ton open hearth furnaces, four rolling mills and a large modern by-product coke



plant of 100 Kopper's ovens, with a capacity of 1,200 tons daily. Subsidiary to Marquette Iron Company is the Marquette Ore Company, owning properties in the Marquette range and conducting the parent company's mining operations. In addition it owns the lease on the Maroco mine in Minnesota, now being stripped and equipped with a washing plant. C. B. Dunster, Cleveland, is general manager of the Marquette Ore Company, which will succeed E. N. Breitung & Co., Inc., 9 Hanover street, New York, was organized a few weeks ago, and John W. Peddie resigned as vice president of the Garfield National Bank, New York, to become president of the company. Mr. Dougherty becomes a director of Breitung & Co., Inc.

V V

G. Cook Kimball has been elected vice president of the Harvard Alumni Association for the coming year. Mr. Kimball is chief engineer of the American Sheet & Tin Plate Company, Pittsburgh.

V V

J. D. Corcoran, formerly works manager of the Hydraulic Pressed Steel Company, Cleveland, recently was elected president of the Sharon Pressed Steel Company, Sharon, Pa., to succeed Josiah Kirby.

V V

Robert W. Early, who for the past 12 years has been connected with the claim department of the American Sheet & Tin Plate Co., has been placed in charge as resident manager of the new branch office, recently established at 628 Jenkins Building Pittsburgh, by Fairbanks & Co., Wade Building, Cleveland, O., sellers of iron ore, pig iron, steel, coal and coke.

V V

John P. Bindley, who on October 26, was elected chairman of the board of the Pittsburgh Steel Company, Pittsburgh, a newly-created position, became that company's president early in 1919, when he succeeded the late Wallace H. Rowe. Mr. Bindley has been affiliated with the company since its inception in 1902, having been associated with Mr. Rowe in its organization. Mr. Bindley was born in Pittsburgh about 73 years ago and always has made that city his home. His business career started with John England in 1860 in a retail hardware business. Later Mr. Bindley purchased the business and formed the Bindley Hardware Company. In 1892 it took over the sale of the products of the Pittsburgh Wire Company, Braddock, Pa., which later was merged with the American Steel & Wire Co. This marked the beginning of Mr. Bindley's connection with the steel and wire manufacturing business. In 1906 he succeeded his brother, Edwin Bindley, as vice president of the Pittsburgh Steel Company. Mr. Bindley is a director of the Pittsburgh Steel Products Company, president of the Neely Nut & Bolt Co. and is a director of several other Pittsburgh enterprises. He is past president of the National Hardware Jobbers' Association and has served a number of terms as president of the Pittsburgh Chamber of Commerce.

V V

Capt. John R. Sproul, son of Gov. William C. Sproul, of Pennsylvania, who is extensively interested in iron and steel plants, has entered the business. He is connected with the Lebanon Valley Iron Company, at Lebanon, Pa.

V V

E. S. Edmunds, formerly of the mechanical department of Jones & Laughlin Southside works, has resigned his position to accept a position as head of the mechanical department of the Pittsburgh Spike & Bolt Co.

V V

William F. Hart has resigned as vice president of the Central Tool Works, Pittsburgh, to become president of the Vernon Tool Works, Oakmont, Pa., succeeding Harry S. Paul, who has sold the controlling interest in the company to Alexander Laughlin and has retired.

V V

Albert G. Dowden, special agent of the American Steel Export Company, in charge of sales of tin plates and sheets, has associated himself with C. S. Davis & Co., Inc., jobbers in tin plates and sheets, Peoples Gas Building, Chicago. As vice president of the company he will take charge of Eastern sales, opening offices and warehouse in the Bush Terminal, Brooklyn, N. Y. At a later date it is intended to open a warehouse in Pittsburgh. Mr. Dowden was formerly in the sales forces of the American Sheet & Tin Plate Company and the Weirton Steel Company, Weirton, W. Va.

V V

S. R. Robinson, 510 South Constoga street, Philadelphia, Pa., who was formerly metallurgist for the Philadelphia Roll & Machine Co., is now metallurgist for the Sandusky Foundry & Machine Co., Sandusky, O.

# NEWS OF THE PLANTS

The Toledo Crane Company, main office and works, Bucyrus, Ohio, chartered under the laws of the state of Ohio, with an authorized capitalization of $600,000 subscribed and paid in, will on January 1, 1921, succeed The Toledo Bridge & Crane Company, of Toledo, Ohio, as builders of "Toledo Cranes."

The new company has purchased all drawings, patterns, records, and every item pertaining to the crane business, and the transfer will be made without any interruption.

W. F. Billingsley, of the Toledo Bridge & Crane Co., will hold an executive position and will have with him intact the crane department organization of that company.

The plant of The Toledo Crane Company will consist of a machine shop, 60 feet x 300 feet, a structural or girder shop, 90 feet x 300 feet, an assembly shop, 120 feet x 320 feet, pattern shop and storage 75 feet x 200 feet, forge shop, 40 feet x 100 feet, which will be fully equipped and ready for production by January 1.

Until January 1 all communications should be addressed to The Toledo Crane Company, at Toledo, Ohio, after January 1, Bucyrus, Ohio.

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As a result of operations of their No. 2 blast furnace, which was recently remodeled, the LaBelle Iron Works, Steubenville, O., have commissioned Arthur G. McKee & Co., 2422 Euclid avenue, Cleveland, to redesign the furnace top structure of their No. 1 furnace. McKee & Co. will also furnish the materials required in the reconstruction of the furnace top, including a McKee Revolving Distributor, bell operating equipment, skip bridge extension, etc.

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The Hanna Furnace Company, Cleveland, O., has been organized by interests of M. A. Hanna & Co., comprising a consolidation of three prominent blast furnace companies and one iron-ore mining company. The blast furnace organizaitons include the Detroit Iron & Steel Co., Detroit, Mich., with two local furnaces; the United Iron & Steel Co., West Middlesex, Pa., operating the Fannie Furnace at this location, a furnace at Cherry Valley, Pa., and large properties at Leetonia, O., consisting of a battery of over 200 beehive coke ovens, and extensive coal properties; and the Penn Iron & Steel Co., Dover, O., operating a local furnace and by-product coke plant. The Ore Mining Company is known as the Hollister Mining Company, Crystal Falls, Mich., operating extensive mines on the Menominee Range at this point. The merger will also include the properties of the Buffalo Union Furnace Company, Buffalo, N. Y., which will be operated under lease covering a period of 40 years with option to purchase at a fixed sum at any time after the expiration of 20 years. The new furnace company will inaugurate operations with assets stated to be about $19,500,000, and was recently incorporated under Delaware laws. It will have a total of eight blast furnaces, with aggregate capacity of from 900,000 to 1,000,000 tons of pig iron per year. The company's individual ore facilities will supply about 50 per cent of its annual requirements, and about 75 per cent of coke demands will also be of company production, or secured under desirable long-term contracts.

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The Red River Iron Company, Clarksville, Tenn., is planning for extensions and improvements in its plant. The furnace has been blown out for relining, etc.

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The Hancock Steel Company, Hancock, Md., has been organized under West Virginia laws with capital of $500,000 to manufacture iron, steel, manganese, brass, bronze and allied products. The company has acquired property at Brosius, W. Va., on the Potomac river, opposite Hancock, comprising about 20 acres of land and is having plans prepared for the construction of a new plant to occupy a portion of this site. The company is understood to be negotiating for the acquisition of a few small iron working plants in this district and will consolidate these interests at its new main works. It is planned to provide equipment and initial operating force for about 500 men. The officials of the company are J. Frank Fields, president; W. Riley Davis, vice-president; and Roy W. Daniels, secretary-treasurer, all of Hancock.

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The Cleveland Cold-Drawn Steel Company, Cleveland, O., recently organized with a capital of $2,000,000, has plans under way for the construction of a new plant on Dunham Road. The company has acquired property aggregating about six acres in this section, with frontage on the Pennsylvania railroad. The first unit of the new plant will be about 100 x 400 feet, and will be equipped for the production of high grade, cold-drawn steel. On the completion of this building, it is proposed to construct a modern heat-treating plant. Actual construction work will be deferred, it is understood, until early in the coming spring. Officers of the new company include: Frank R. Kew, president, now general superintendent of the Crucible Steel Company of America, Pittsburgh; H. B. Barnard, vice-president, now acting as works manager for the Crucible Steel Company; and A. P. Stressinger, secretary-treasurer, connected with the International Steel Tube Company, Cleveland. W. W. Wallace and C. H. Hopkins will be directors of the new organization; the latter is treasurer of the International Steel Tube Company.

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The St. Louis Coke & Chemical Company, Granite City, Ill., will soon blow in its new blast furnace now nearing completion. The unit has a rating of 600 tons, and will be used in connection with a battery of 80 coke ovens, and about one-half of which will be placed in service at the time that the furnace is blown in. The coke plant will produce metallurgical coke, using Illinois coal exclusively; a portion of the coke output will be utilized in the blast furnace. The major pig iron production will be sent to the plant of the National Enameling & Stamping Co., in this vicinity, while the remainder will be disposed of under regular commercial sale.

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The American Tube Works, 10 Oliver street, Boston, Mass., manufacturer of seamless tubing, etc., with plant at 440 Somerville avenue, Somerville, Boston, has awarded a building contract to the Whidden-Beekman Company, 100 Boylston street, Boston, for the erection of an addition to its plant for increased production. The structure will be one and one-half story, brick and steel, and is estimated to cost about $75,000, including equipment.

# Some Pointers on By-Product Coke Oven Operations

## GAS REQUIREMENTS OF THE BY-PRODUCT OVEN.

At present, it is the usual practice to employ part of the gas produced in the coking operation for heating the ovens. With the development of the modern regenerative oven, a high degree of heating efficiency has been obtained and the records of a number of Koppers plants show less than 40 per cent of the total gas used in coking the coal. This amounts to approximately eight per cent of the calorific value of the coal. The remainder of the gas, amounting to from 6000 cubic feet to 7000 cubic feet per net ton of coal charged, is surplus available for use outside of the plant and may be either straight gas or "rich gas." In the first case, the surplus gas is simply an average of the total gas produced and has the same composition as the portion used for heating the ovens. In the second case, the plant must have a system of gas separation wherein the "rich gas", produced in the earlier stages of the coking process and containing higher percentages of hydrocarbons which gives it a higher heating value, is withdrawn and treated in a separate system of apparatus, while the lean gas, produced in the later stages of coking, is treated separately and used for heating the ovens. With properly selected coals, the modern by-product coke plant will produce straight gas having a heating value of 560 Btu per cubic foot after removal of benzols. It is usually assumed that gas separation will be necessary if local requirements call for a heating value of more than 560 Btu per cubic foot, unless the benzols are allowed to remain in the gas. The estimates in any case depend upon the kind of coal available. With gas separation, it is easy to produce surplus gas of over 600 Btu per cubic foot, and the heating value may be still further increased by the use of benzol obtained from the lean gas to enrich the rich gas; but we believe that little consideration should be given to any proposition of supplying gas containing benzols. Considering the matter in its broadest aspect, apart from any arbitrary local standards, gas separation will, in most cases, be found not to be worth the additional investment and expense required. From an economic standpoint, the interests of the gas producing company and consumer are identical and both are beginning to recognize that the old standards of high candle power and high heating value are expensive and unnecessary. The present tendency, in building by-product coke plants for gas manufacturing purposes, is to eliminate gas separation and provide straight gas from which the benzols have been removed.

Modern by-product coke oven engineering has not been content with the saving of 60 per cent of the total gas produced as surplus, but has found means to render the entire production of gas available for use outside the plant. This has been accomplished by the utilization of producer gas for heating the ovens. As will be noted later, blast furnace gas or other low grade gases may be substituted for producer gas. In the use of such gases, preheating is essential, and the most economical means in combination with the by-product coke oven has been achieved in the Koppers combination oven, which will be described in a later section of this paper. This oven may be heated either with producer gas or with coke oven gas and affords the maximum flexibility with respect to gas production. The combination oven is of special importance from the standpoint of the natural gas interests. It is indispensable for any plant built primarily for the manufacture of gas and may soon even be considered indispensable to by-product coke plants affiliated with the iron and steel industry, as will be shown in the next section.

### Gas Requirements of the Iron and Steel Industry.

In any consideration of the by-product coke industry, we cannot neglect its intimate relation with the iron and steel industry, and this relation profoundly affects any estimates that may be made in connection with the utilization of coke oven gas. More than 90 per cent of the coke manufactured in the United States is used in iron and steel manufacture. Although it is true that many plants have been built altogether apart from iron and steel plants for the primary purpose of gas production, nevertheless, under present conditions, most of these plants depend very largely upon blast furnaces and foundries for the bulk of their coke sales. The majority of the by-product coke plants are built in conjunction with the iron and steel works that they serve, and it is universally agreed that this close relation is to the best interests of the iron and steel industry. The availability of coke oven gas for various uses around the iron and steel works is one of the principal reasons why this is true.

During recent years, much thought has been given to the economic balancing of the fuels produced in iron and steel manufacture. It is generally agreed that a complete steel plant comprising blast furnaces, open hearth furnaces, rolling mills and by-product coke ovens will need all of its blast furnace gas and all of its surplus coke oven gas for its own use. In addition, the coke oven tar has been found to be excellently adapted for heating open hearth furnaces. In the case of merchant blast furnace plants manufacturing their own by-product coke, very little of the surplus coke oven gas is needed on the plant, and practically all may be sold.

What then are the prospects of obtaining coke oven gas from iron and steel plants operating their own by-product coke ovens?

1. As has been stated, practically all of the surplus coke oven gas from merchant furnace plants is available. To this may be added such additional coke oven gas as may be obtained by using producer or blast furnace gas for heating the ovens.
2. Considerable quantities of coke oven gas are wasted at steel plants during week-end shut downs. The amount of this depends upon local conditions and is very difficult to estimate; but in many cases this possible source of supply is worth investigating.
3. Steel plants using all their surplus coke oven gas may, under certain conditions, find inducement to use producer gas for heating the coke ovens, thus releasing considerable quantities of high grade gas for sale.

Since it may be fairly assumed that all the surplus gas produced by coke ovens operating in conjunction with merchant furnaces is already being utilized, the question of obtaining further supplies of gas from existing installations is, therefore, narrowed down to the probable relief that might be afforded by the substitution of producer gas for oven heating. We are at once confronted with the fact that no plant of by-product coke ovens operating as a part of an iron and steel plant, is now adapted to the economical utilization of producer gas. The combination oven is the only type that can use producer gas with the requisite degree of efficiency.

## TRADE NOTES

The Trumbull-Cliffs Furnace Company have placed an order with Arthur G. McKee & Co., Cleveland, which covers the furnishing of a McKee Revolving Distributor for their new blast furnace at Warren, O.

L. C. Wilson, for the past two years general sales manager of the Chain Belt Company, Milwaukee, has been elected secretary of the Federal Malleable Company, West Allis, Wisconsin, manufacturers of malleable castings, malleable chain and the Rapid Molding Machine. He is to assume his new duties on November 15th and will be succeeded as sales manager at the Chain Belt Company by Clifford F. Messinger.

W. S. Quigley, president Quigley Furnace Specialties Company, New York City, has just returned from Europe after an extensive trip made in connection with large installations of the Quigley Powdered Coal System in Italy and Belgium.

Freyn, Brassert & Co., engineers, Chicago, have been appointed consulting engineers for the Royal Netherlands Blast Furnace and Steel Works Company, The Hague, and plans and purchases are under way for the construction of two blast furnaces at Ijmuiden, Holland. The plant is planned along American lines throughout, inclusive of furnaces, hot blast stoves, gas washing, ferro-concrete bins, charging, blowing and other equipment.

The J. B. Engineering Sales Company have been appointed Connecticut sales agents of the Conveyors Corporation. Offices are locaetd at 60 Prospect street, Hartford, Conn.

W. L. Goodrich of Springfield, Mass., has been appointed to the New England territory by N. & G. Taylor Co., of Philadelphia, for the sale of their forging steel.

Four Type "G" Smith Gas Producers have just been ordered by the Electric Storage Battery Company, of Philadelphia, for use in connection with lead melting furnaces. The cold, cleaned gas generated by these producers will replace the use of city gas. The unique features of the Smith Producers to be installed is the mechanical poking device which greatly reduces labor requirements and makes possible an unusually deep fuel bed which, according to the manufacturer's claims, is highly desirable. The cleaning equipment furnished with this type of producer is the Smith Type "F" tar extractor containing diaphragms of spun wool which cause tar particles to agglomerate and fall out of the gas current. The cleaning equipment is guaranteed to remove 99.5 per cent of the tar from the gas, so that it can be used in the former natural gas mains. The manufacturer is the Smith Gas Engineering Company, of Dayton, O., and Lexington, O.

The Pulaski Iron Company announces the appointment of Richard Peters, Jr., as manager of sales of its pig iron, with headquarters at the above address. This appointment is made for the purpose of dealing directly with all customers and also to provide for the best possible service.

The Valley Smokeless Coal Company announces that all purchasing will be done from the offices of Weston Dodson & Co., Inc., Bethlehem, Pa., and affiliated companies. J. B. Connell is general purchasing agent.

The office of F. E. Clark, deputy commissioner of the Tidewater Coal Exchange, Inc., has been removed to the Dencla Building, Tenth and Market streets, Philadelphia, Pa.

## TRADE PUBLICATIONS

Recent publications on C-H Space Heaters include a "Dictionary of Uses" and a folder on the "Protecting of Sprinkler Systems." The dictionary is a two-color, 64-page, 4 x 8¾ booklet, known as Publication 867. A few pages of this booklet are devoted to the general subject of electrical heating of air, with thumb rules for estimating the number of heaters required, and a description of these two-foot lengths of standardized heaters, which are commonly referred to as "Two Feet of Electrical Heat," and which may be connected to lighting and power circuits like electric lamps. The rest of the booklet gives excerpts from letters in which users of these heaters describe the uses to which they have been put. Over a hundred different applications of these heaters are mentioned, and many more uses are suggested.

"Protecting the Sprinkler System Against Freezing" is the title of a two-color 4-page envelope size folder, also descriptive of C-H Space Heaters. This folder, Publication 863, describes how Space Heaters are used to keep sprinkler systems effective in the coldest weather. Views of Space Heaters installed in riser valve houses are shown, and data are given to assist in determining the number of heaters required.

Both of these publications are being distributed by The Cutler-Hammer Mfg. Co., of Milwaukee and New York.

"Webster Method." The Webster Manufacturing Company, Chicago, Ill., containing articles and photographs of recent interesting installations in the coal mining and other fields.

"Traveling Water Screens," 24 pages. The Link-Belt Company, 910 S. Michigan avenue, Chicago, Ill. This publication will be sent to anyone interested in the effective and economical screening of condensing water. Surface condensers are easily clogged up by trash contained in the water supply, and very hard to clean. Clogged condenser tubes mean reduced efficiency of operation and other disadvantages that can be forestalled by the use of traveling screens. This interesting subject is covered fully.

"Dorman Wave Power Tools." W. H. Dorman & Co., Ltd., Stafford, England; 68 pages, 8½ x 11 inches; illustrated. The first of a series of appliances originated and designed by sole British licensees and manufacturers of wave portable, percussion and rotary tools.

The Commission of Conservation, Ottawa, Canada, has published a pamphlet from a report on "Pulverized Fuel, Its Uses and Possibilities." W. J. Dick, the author, is a recognized authority on Canada's fuel and power problems, and his research work has gone far toward indicating the methods by which these may be solved. Copies of the pamphlet are freely obtainable on request to the commission.

"Control of Motor-Driven Steel Mill Machinery." The Cutler-Hammer Manufacturing Company, Milwaukee, Wis., publication 870; 48 pages, 8 x 11 inches, illustrated. Describing C-H products used in mining and ore handling, furnace and mill practice.

Arthur D. Little, Inc., Chemists and Engineers, has just announced that a limited number of copies of a monograph on "The Petroleum Outlook," are now available for distribution to bankers, brokers, manufacturers and investors free of charge on application. This work comprises an economic study of "The Petroleum Outlook," with especial reference to American fields, a large map and several charts, arranged for comparative reference, with an illuminating discussion of the status of the numerous oil fields.

Blaw Knox Company have recently published some very complete folders entitled, "Blaw Knox Buckets," and "A Discussion of Lever Arms." They will be sent upon request.

The Whiting Corporation has just published a complete booklet, "Foundries, Their Complete Equipment," which covers in a general way the layout and equipment of way the layout and equipment of com-complete foundry plants.

The United Electric Light & Power Co., subsidiary of the New York Edison Company, have purchased 12 1900 hp Springfield Cross Drum Boilers, designed for 300 pounds steam pressure, for their new Hell Gate plant. This plant when completed will be the largest generating station in the world.

The Springfield Boiler Company is represented in the Pittsburgh district by the Rush Machinery Company, 932 Oliver Building, who are now installing two 1500 hp 300 pound pressure boilers for the Youngstown Sheet & Tube Co., and two 760 hp 275 pound pressure for the National Tube Company.

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